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Cartography, Discourse, and Disease: How Maps Shape Scientific Thought about Disease

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CARTOGRAPHY, DISCOURSE, AND DISEASE

HOW MAPS SHAPE SCIENTIFIC KNOWLEDGE ABOUT DISEASE

by

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Under the Direction of Jeremy Crampton

ABSTRACT

This research examines public health mapping over two time periods, 1944-1954 and 2000-2004 and explores how mapping disease shaped scientific knowledge about disease. During World War II, the *Atlas of Diseases* was produced by cartographers and geographers well versed in the subjectivity of maps. Today professionals in a variety of disciplines use digital mapping software to produce maps of disease. This research takes a look at how public health maps and mapping of disease have changed over time and discusses the political implications of public health mapping as an aspect of geographic governance.

INDEX WORDS: disease mapping, medical geography, medical cartography, Atlas of Diseases, geographic governance

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The number of hours spent behind the computer, in the library and tucked deep within the AGS archives cannot compare to the number of hours my husband had to listen to me work out the challenges of disease mapping. This research is dedicated to Chris Martin for his unconditional love that made sure I never lost my way.

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Chapter 1. Purpose of Study

The purpose of this research is to understand how maps shape scientific knowledge about disease. Although mapping technology continues to change over time, it is important to understand the power of mapping as a function of acquiring geographic knowledge about the distribution of disease. "How geographers represent geographic space, what spatial information is represented, and what space means in an age of advanced computer and telecommunications technology are critical to geography and to society. (National Research Council 1997)." Over time disease mapping has shed light on political interests in understanding the geographic distribution of disease. Following Foucault's concept of governmentality, the relationship between public health and disease mapping are discussed in terms of power-relations and is used to explain how maps and mapping are ways of politically understanding the geographic distribution of disease. Using Foucault's historical analysis of government and political thought as a model, the historical analysis of disease mapping provides insight into the challenges that historically faced geographers and public health researchers in order to gain perspective and provide alternative strategies for addressing modern challenges of mapping disease.

This research examines disease mapping in two time periods, 1944-1954 and 2000-2004. Chapter two examines a 10-year period when the American Geographical Society published a series of maps called the *Atlas of Diseases* in the *Geographical Review*, 1950-1954. The first meeting of medical doctors and geographers occurred in 1944, the third year of the United States participation in World War II. The atlas was the first real attempt to represent medical geographic data cartographically and was truly innovative because relationships between the environment and disease had never been visualized globally before. The influence of war acted as a catalyst in expanding geographic knowledge about diseases. The exposure of thousands of US military to disease propelled medicine to top priority. Paralleling the scientific formalization of thematic mapping, acquired knowledge of disease via the military promoted a global shift in the perception of disease. Diseases once thought to only be endemic overseas and across borders were now taking the lives of American troops and civilians.

The second part of this analysis looks at the number and types of maps published in a select sample of the public health literature 2000-2004 to assess mapping as a way of politically understanding people, place, and disease. Assessing the total number and types of maps published in the journals gives meaning to the relationship between map type, the subject of study (infectious disease, chronic disease, etc), and the type of data available for analysis. A content analysis is performed in Chapter three to examine six journals, one cartographic publication and five leading public health and GIS publications, for the number and kinds of maps published 2000 to 2004. Chapter four returns to public health mapping as governance and discusses maps and mapping in the political understanding of the geographic distribution of disease.

Public Health and GIS

Interest in public health mapping has increased over the last decade. In fact, new disciplines devoted specifically to public health and GIS are emerging from common interests of epidemiologists, geographers, and cartographers to produce meaningful maps that provide insight into the underlying processes of disease. GIS is a "database system with specific capabilities for spatially-referenced data", as well as a set of operations for collecting, organizing, and analyzing the data (Star and Estes 1990 p.2). Geographers and public health professionals have produced a significant body of work examining GIS and mapping techniques best suited for mapping and spatially understanding public health information. Over the last 25 years this work has focused on the practice of thematic mapping (Wright 1942; Robinson 1982; Brewer, MacEachren et al. 1997; Pickle, Mungiole et al. 1997; Bithell 2000; Brewer and Pickle 2002; Cromley and McLafferty 2002; Boscoe and Pickle 2003) and more recently, geospatial techniques such as areal interpolation have been explored (Bithell 2000; Edsall 2003; Rushton 2003).

Maps are defined as "graphic representations that facilitate a spatial understanding of things, concepts, conditions, and processes, or events in the human world." (Harley and Woodward 1987 p. xvi) Mapping, or the symbol making process, organizes knowledge and how information is symbolically represented can shape the character of a place (Robinson and Petchenik 1976 p46). Maps not only present characteristics of a place, but the mapping process itself is a means by which knowledge can be gained about a particular place or places. This knowledge is structured in a certain and important way that is developed through the choices made about what is put on maps and how that information is represented. This knowledge is not necessarily 'read from the map.'

Where a person lives is the primary geographic distribution considered in public health and epidemiology. Mapping case locations at the individual or population level are important to public health research because the spatial distributions provide insights into the environment where potential exposures of health risks may be encountered (Cromley and McLafferty 2002). Public health applications of GIS are used to map the source and distribution of disease agents, identify areas where people may be exposed to environmental and biological contaminants, and analyze the spatial and temporal patterns of different health outcomes (Cromley and McLafferty 2002). Health, Census, economic, income, unemployment, labor, crime, transportation and other vital statistics are easily related to a geographic database using GIS. Linking the residential address of a newly diagnosed tuberculosis patient with demographic data provided by the US Census Bureau, for example, can be an effective method for identifying clusters of high incidence that can enhance targeted screening and control efforts (Moonan, Bayona et al. 2004).

Mapping as governance

The relationship between public health and mapping began in the mid nineteenth century. The mid 1850s marked rapid development and urbanization in developing countries. The development of large centralized populations in economic and industrial centers such as London and New York City put people at greater risk for disease like cholera, yellow fever and others associated with poor sanitation and hygiene. In order to improve and manage sanitation, hygiene, and nutrition, it was important to understand where and how the majority of the population lived (Robinson 1982). Dr. John Snow famously linked public health and mapping when he identified the source of a cholera outbreak in downtown London in 1854. Using a dot map to visualize the relative locations of cholera cases, Snow could see the spatial distribution of cases seemed to occur around a fixed location, the Broad Street pump (Figure 1.1). Snow is also famous for linking maps

Figure 1.1 John Snow's map of cholera deaths in downtown London, 1854.
(Source: http://www.ph.ucla.edu/epi/snow/snowmap_1854.jpg)

to health intervention as the removal of the pump handle is suggested to have led to the end of the outbreak (Robinson 1982; McLeod 2000; Vinten-Johansen, et al. 2003).

Historically, medical geographers and public health professionals were not the first to create maps of disease. Statisticians and political economists invented thematic mapping in the early 19th century to provide knowledge about populations that enabled the governing of large masses of people (Robinson 1982; Foucault 2000; Crampton 2004). The process of mapping statistics was a form of governance and builds on Foucault's concept of governmentality that describes the concept of governing of oneself and of governing others. Geographic governance is a term given to the use of mapping as it pertains to the political decision making process of government. When applied in geography, geographic governance can be used to understand the political implications of mapping by political boundaries as constructed by choropleth mapping (Crampton 2004).

The French political economist Charles Dupin used the first known choropleth in 1826 (Robinson 1953). Dupin shaded administrative districts to represent the relationship between the prosperity of France and the ratio of male children that were in school. The choropleth was quickly adopted to represent information collected by the newly formed census that provided social knowledge of color, race, sex, age, marital status, illiteracy, ownership of homes, occupations, and prevalence of disease. This information provided a picture of where things were so the appropriate disposition of resources and policies could be developed to govern and regulate the territory. Understanding the population in statistical terms allowed human variation to be placed under a distribution curve to determine what was normal. "Normalcy" was the key to governing large masses of people. This type of surveillance, or geographic governance, allowed for populations across a territory to be compared for rates of disease, education, income, or any other issue necessary for policy making and government (Robinson 1982; Foucault 2000; Crampton 2004).

Governmentality is a term defined by Foucault to describe the onset of the novel form of government that emerged in the 16^{th} century. Up until this time, territories were under sovereign rule whereby it was the divine right of the monarchy to rule the principality as seen fit. By the 18^{th} century feudalism had ended, colonial states were being established and economy was introduced into the political arena. Here political economy represents the governance of the state, its inhabitants, and all of the complex processes and ways that the inhabitants relate to the territory and other things such as customs, death, and epidemics. In order to govern efficiently, the government implemented surveys, questionnaires, and censuses to systematically collect observations about the population including information regarding the individuals, their goods, health and wealth. It is the 'art of government' that describes the analysis of the correct way of managing individuals, goods, health and wealth. Since the 16^{th} century, statistics have revealed the characteristics of a population in terms of birth rates and death rates, disease, and epidemics that were used for the purpose of government to maintain the welfare, wealth, longevity, and health of the population (Foucault 2000). This was a new kind of governmentality where health can be seen as one aspect of individual daily life (Williamson 2004).

Foucault defines the collection of information as the management of the modern state, a modern state that distributes forms of governmental power through surveillance. His discussion of Panopticism in *Discipline and Punish* begins with a dramatic description of the plague epidemics during the 17^{th} century where quarantines were implemented under the authority of the militia for the centralized registration of the pathology and management or control of medical treatment. A panopticon is an architectural structure where rooms are arranged around a central tower such that each occupant's behavior remains visible to the supervisor at all times. Foucault uses the spatial arrangement of the panopticon as a metaphor for the dividing power of governance. This metaphor draws a relationship between the power and order of quarantine and a centralized surveillance with the treatment of disease. "First, a strict spatial partitioning: the closing of the town and its outlying districts, a prohibition to leave the town on pain of death, the killing of al stray animals; the division of the town into district quarters each governed by an intendant. Each street is placed under the authority of a syndic, who keeps it under surveillance; if he leaves the street, he will be condemned to death (Foucault 1977 p.195)." In the discipline of the quarantine, each individual is fixed in an enclosed, segmented place with all actions observed and if the rules of quarantine are broken, punishment or disease is the consequence (Foucault 1977).

The dividing power of governance became immediately problematic in the early 19th century when disciplinary controls became universalized. Just as plague-stricken communities underwent disciplinary partitioning, lepers were also excluded from society. In efforts to "perfectly govern society", disciplinary actions that individualized the excluded, in the process 'marked exclusion'. The processes of measuring, observing, and treating (correcting) implemented by surveillance was a type of branding, whereby those with disease became susceptible to the division between normal and 'abnormal' (Foucault 2000 p.199).

The chronological development of the atlas, including who was involved and why they wanted to produce the maps, is presented as a case study to understand how mapping shaped geographic knowledge about disease. The development of the atlas is discussed in the context of World War II and the influence war had on reviving new interests in medical geography. The next section takes a look at the achievements of the atlas as a classic and important initiative in history.

Chapter 2. The Atlas of Diseases

In 1950, the first map in the series of maps of the American Geographical Society's (AGS) *Atlas of Diseases* was published in the *Geographical Review* (GR). Each plate represented infectious and noninfectious diseases important to civilian and military government occupied areas and to the public health of the United States. Authored by Dr. Jacques M. May, each of the seventeen plates presents the distribution of diseases using the Breisemeister elliptical equal area projection. In addition to the main world map, several small-scale world maps and/or large-scale insets of critical areas for the particular disease were included for comparison. Shading or symbols are used to mark the presence or absence of the disease, the severity of infection rates, the period of occurrence, and the distribution of environmental factors correlated with disease. In some cases, arrows were used to illustrate the spread of disease as in the first plate published entitled "The World Distribution of Cholera 1816 –1950 (May 1951)." Each plate of the atlas was published in loose-leaf form and published in a periodical format to increase circulation and reach a broad audience of geographers, medical scientists, students, and others interested in medical geographic studies. The following is a list of the maps published in the Ge*ographical Review* (Table 2.1).

Table 2.1 The *Atlas of Diseases*. The number refers to the plate number followed by the title of the map and date it was published.

1	*Map of the World Distribution of Poliomyelitis*	*Oct 1950*
2	*Map of the World Distribution of Cholera*	*Apr 1951*
3	*Map of the World Distribution of Malaria Vectors*	*Oct 1951*
4	*Map of the World Distribution of Helminthiases*	*Jan 1952*
5	*Map of the World Distribution of Dengue and Yellow Fever*	*Apr 1952*
6	*Map of the World Distribution of Plague, 1900 - 1952*	*Oct 1952*
7	*Map of the World Distribution of Leprosy, 1952*	*Jan 1953*
8	*The Mapping of Human Starvation*	*Apr 1953*
9	*The Mapping of Human Starvation: Diets and Diseases*	*Jul 1953*
10	*Map of the World Distribution of Rickettsial Diseases*	*Jan 1954*
11	*Map of the World Distribution of Rickettsial Diseases*	*Jan 1954*
12	*Map of the World Distribution of Rickettsial Diseases*	*Jan 1954*
13	*Map of the World Distributions of Some Viral Encephalitides*	*Jul 1954*
14	*Map of the World Distribution of Leishmaniasis*	*Oct 1954*
15	*Map of the World Distribution of Spirochetal Diseases: 1. Yaws, Pinta, Bejel*	*Not published*
16	*Map of the World Distribution of Spirochetal Diseases: 2. Relapsing Fevers Louse-borne & Tick-borne*	*Not published*
17	*Map of the World Distribution of Spirochetal Diseases: 3. Leptospiroses*	*Not published*

(Source: *Geographical Review* 1950-1954)

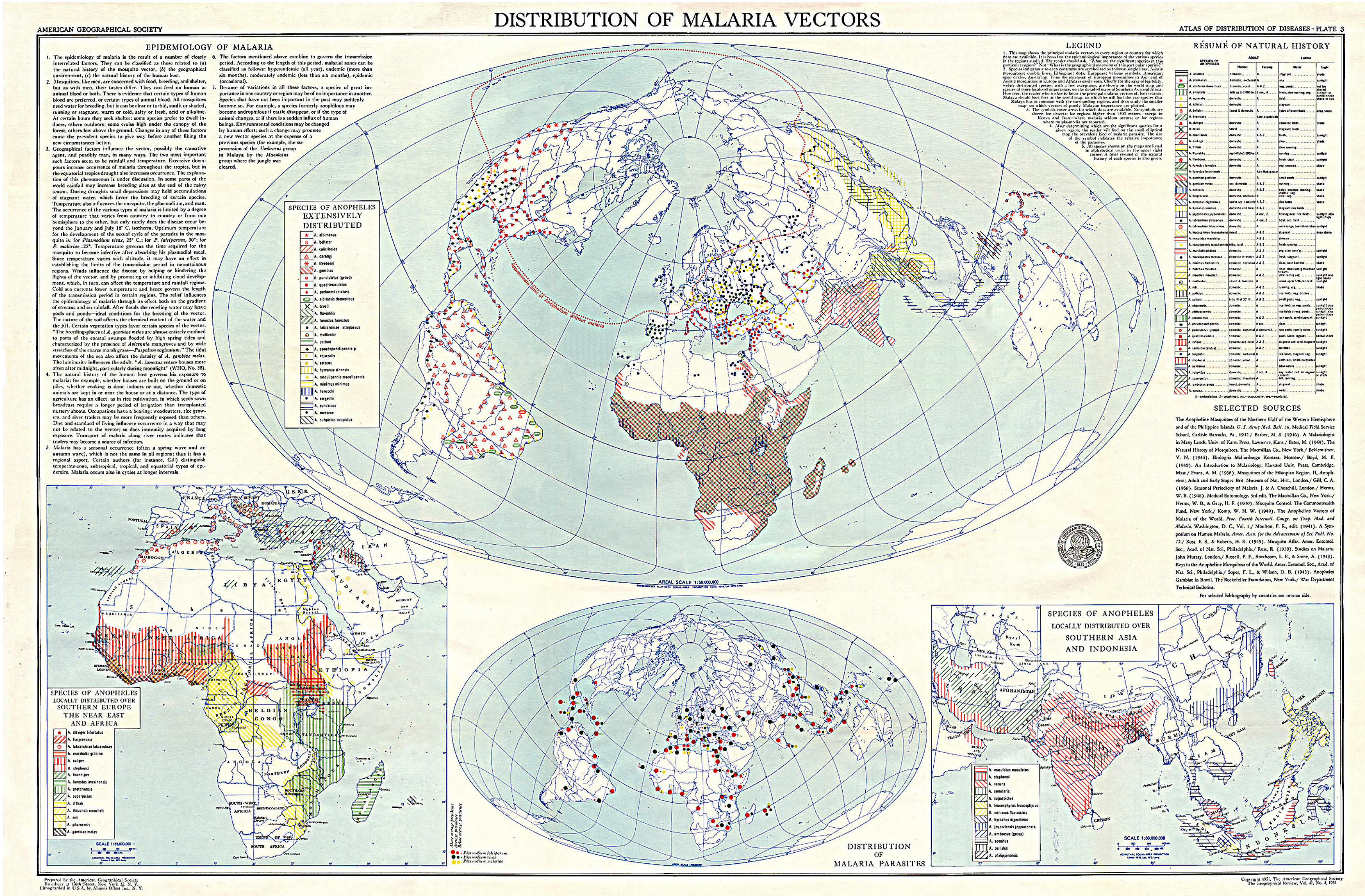


Figure 2.1 The World Distribution of Malaria Vectors (May 1951)

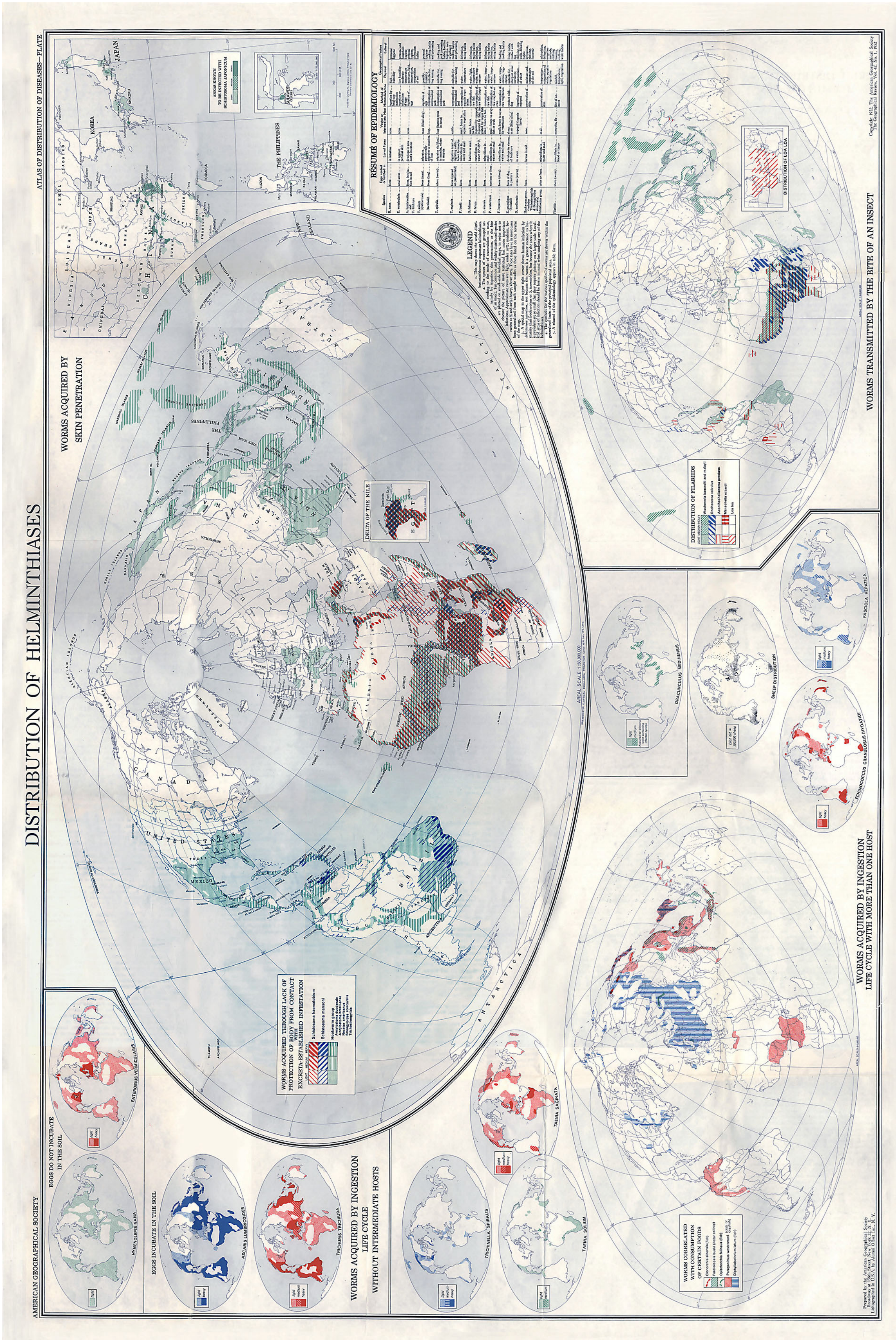


Figure 2.2 World Distribution of Helminthiases (May 1952)

The atlas was produced under the general supervision of Dr. Richard Upjohn Light, a neurosurgeon and member of the Council, as a joint undertaking of the AGS and representatives of the medical profession. Light, inspired and prompted by Miss Wrigley, editor of the GR and familiar with the geographic studies health and disease, solicited the assistance and expertise of Dr. J.K. Wright, then Director of the AGS (Wright 1952). Together the two prepared a proposal for the *Atlas of Diseases* that Light presented to the Society on February 29, 1944.[i] The Society regarded the atlas as a project in scientific research and felt it was a priority to show how a tool can be developed. The function of the AGS was to organize, promote, and seek funds for the project as well as to draw, edit, and publish the maps and accompanying text. The function of the medical scientists was to furnish a steering committee. The committee advised the Society and appointed specialists best adept at gathering, compiling, and writing about the chosen diseases. It was not the intention of the Society to draw upon the knowledge of medical professionals. It was with the guidance and help of medical men, that the project would have "respectability in the eyes of the medical profession."[ii]

The fundamental purpose of the atlas was to illustrate the correlation of disease with the natural and social environment. No systematic attempt had been ever been made to represent medical geographic data cartographically. Nor had geographers and medical scientists worked together systematically to survey the 'mutually dependent aspects of their fields.'[iii] In the 1790's, L.L. Finke systematically accumulated medical knowledge gained from explorations of new worlds in the 15th and 16th century in a three-volume work. It is thought that he produced the first world map of disease in 1792, however no copies exist and thus the impact it had on the development of medical cartography is unknown (Barrett

2000). Existing books such as “Handbook of Geographical and Historical Pathology” first published in the 1860’s by August Hirsch and “The Geography of Disease” published in 1903 by F.G. Clemow, among others, written on medical geography were poor (Light 1944). The books recorded where diseases were found, what was being done about them, but why diseases were found in certain regions was “generally neglected.” There was a need to approach the subject from the point of view of the natural and social environment as risk factors for disease.[iv]

A review of the Society’s history revealed that since 1859 there had only been a few papers presented on the study of medical geography (Wright 1952). Of those papers, only one referred specifically to the mapping of disease. In 1852, a physician named E.H. Barton of New Orleans used the medical returns of the United States Census to map the ‘number per thousand of the population’ that suffered from cholera, fever, and intestinal diseases in the states of Louisiana, Mississippi, Arkansas and Texas (Kennedy 1860). In the summer of 1853, New Orleans experienced one of the worst Yellow fever epidemics in the United States. New Orleans was a major port of entry for immigrants and provided easy access to the nation’s interior via the Mississippi River. In an effort to understand characteristics of the environment that contributed to disease, Barton prepared the “Sanitary Map of the City of New Orleans.” Published by The Sanitary Commission of New Orleans in 1854 (Figure 2.3). The map represents ‘the location of various nuisances and other causes affecting the salubrity (health or well-being) of the city as shown in the occurrence of near 30,000 cases of Yellow fever in the Epidemic of 1853; in the districts; in the districts and wards respectively; according to which the U.S. Census was taken in 1850.”

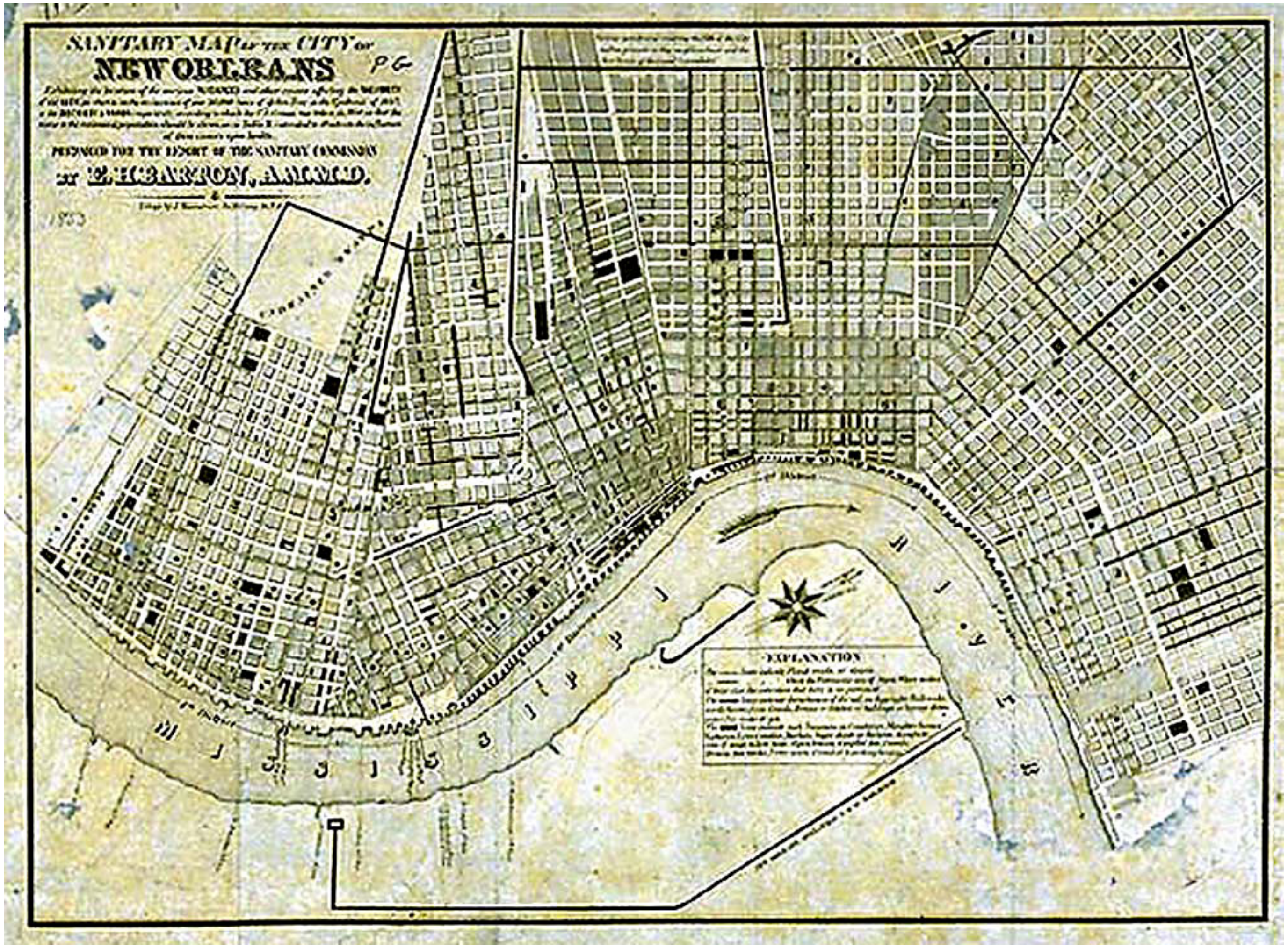


Figure 2.3 “Sanitary Map of the City of New Orleans” by Dr. E.H. Barton, 1854. The lines indicate, “Disturbances of the soil, as digging for railroads, earth thrown from canals, drains or ditches, or buildings or laying down pipes for water or gas.” The shaded areas are nuisances that include “cemeteries, slaughterhouses, vacheries (cow enclosures), livery stables (where horses and carriages are kept), markets, sugar depots on the levee, manufactories of soap, tallow, bone, open basins & unfilled lots, canals, drains, gas works, fevernests, crowded boarding houses.” (http://lsm.crt.state.la.us/lsmmaps/looker.asp?page=966)

Earlier efforts to combine medicine and geography had failed. Dr. Henry Viets, a member of The International Society for Geographical Pathology founded in 1928, intended to broaden the scope of the Society to include the history of diseases. But due to the depression, lack of funding, and the death of the society's president Professor Askanazy, the historical studies were not conducted. The American Climatological Society, developed in 1882 and later known as the American Clinical and Climatological Society was another effort that failed to maintain studies in medical geography (Light 1944).[v]

"The global character of the war" had revived interests in medical geography.[vi] By 1944, the United States had been at war for three years. On December 4, 1941, Japan attacked Pearl Harbor on the Hawaiian Island of Oahu. Four days later, the U.S. congress approved entry into the war. War moved large masses of people to remote regions of the world and brought change to the distributions of disease, environments and the human settlement conditioned by the disease (Light 1944). In contrast to the army of WWI, the army of WWII was twice the size, was mobilized over a longer period of time and over a greater extent of the globe. Soldiers migrated into areas where disease was already prevalent and fueled epidemics. Despite the familiarity with disease, the entry of the United States into World War II found the medical profession unprepared to cope with the increasing number of American troops sent to areas where disease was endemic (Stunkard 1943).

Before the war, malaria was known to exist in areas extending from 45° N and 40° S but it was not certain which areas posed the greatest threat to American soldiers. Malaria crippled U.S. soldiers in the Solomon Islands and the China-Burma-India Theater where the highest incidence rate, 98.46 per 100,000, occurred (Cushing 1957). The United States held positions in North Africa, a seaboard essential to securing the Mediterranean, where soldiers fell victim to poliomyelitis, a disease only thought to afflict children under the age of 5, not men of military age. U.S. presence in these areas was essential because the major land, water, and air routes across the continent connected the U.S. to the Middle East and India providing principal ports of entry (Stembridge 1943).

Medical geographic knowledge of all diseases progressed with WWII, especially those found in tropical regions. In fact, the Medical Intelligence of the Surgeon General's office was also planning to produce a book illustrated with maps.[vii] Volume one of a four-volume work was already in proof stage and covered a selection of material from India, the Far East and the Pacific. Light, however, was confident that the publication would not compete with the atlas. "Following the patterns of medical geographies (or medical pathologies) set in the 19th century, [the] work sounds more like an encyclopedia of disease…" The resource "would be more or less restricted to persons who know about parts of the world other than their own. This type of information was valued during the explorations and migrations of the century but is less of a value as new parts of the world developed independent medical systems (hospitals, medical schools) to cope with the problems on the spot."[viii]

The Conference

On May 20, 1944 the American Geographical Society held a conference of medical doctors and geographers to develop the *Atlas of Diseases* as a tool of scientific research. Accompanying Dr. Light was Dr. J.K. Wright, Director of the AGS, Mr. Roland L. Redmond, President of the AGS, members of the AGS staff and sixteen medical men of academic and military expertise. Mr. Roland M. Redmond, President of the AGS, led the discussion on the fundamental purpose of the atlas.

> "We want the atlas to be a pathfinder, an instrument that will develop techniques…. We look on it as a pioneering project, and yet one that ought to be sufficient in scope to show other people how valuable the type of information presented would be if it were developed" R.M. Redmond[ix]

It was agreed that the atlas include diseases in which important environmental factors were involved. Knowing a steering committee would be appointed to carry out the task of data collection, a preliminary list of diseases was compiled by the scientists present at the conference. Ten diseases, from a list of 44 possible choices, were chosen and ranked based on what each scientist knew about data availability and the significant connection with the environment. In order of importance, the tallied result of the votes were (1) cholera, (2) the typhus group, (3) malaria, (4) yellow fever, (5) goiter, (6) plague, (7) beriberi and pellagra, (8) filariasis, (9) encephalitis, and (10) schistosomiasis (Wright 1944) (Figure 2.4).

Dr. Sawyer, Dr. Deutschman, Colonel Anderson, and Dr. Dunahoo had a lot of experience and knowledge regarding the availability and reliability of information. As Director of the International Health Division at the Rockefeller Center, Dr. W.A. Sawyer had knowledge of areas of the world endemic for yellow fever and malaria. Dr. Zygmunt Deutschman worked for the Millbank Memorial Fund and was familiar with the 25 years of regional studies held by League of Nations Series of Epidemiological Intelligence and Public Health Statistics. Colonel Anderson of the Office of Medical Intelligence at the

	Rank in Dr. Dunnahoo's list*	Anderson	Blake	Deutschman	Dunnahoo	Leake	Light	Longcope	Malloch	Maxcy	Meleny	Paul	Sawyer	Smith	W. H. Wright	Total as recorded at meeting	Total per steno record
Cholera	3	x	x	x	x	x	x	x	x	x	x	x	x	x		13	13
Typhus group	4	x	x	x	x		x	x	x	x	x	x	x	x	x	13	13
Malaria	6	x	x		x	x	x	x	x	x	x	x	x	x	x	12	13
Yellow fever	5	x	x	x	x	x	x	x	x	x	x		x		x	13	12
Goiter		x	x	x	x	x	x	x	x		x	x	x		x	12	12
Plague	2		x	x	x		x	x	x	x	x	x		x	x	11	11
Beriberi and pellagra		x	x	x	x	x	x		x		x	x	x		x	11	11
Filariasis	17	x	x		x	x			x	x	x			x	x	9	9
Encephalitis	12		x				x	x		x	x	x	x		x	8	8
Schistosomiasis	14			x	x				x	x	x		x			8	6
Trypanosomiasis	13	x		x		x		x		x			x			4	6
Sand-fly fever	22					x				x		x	x			4	4
Silicosis		x	x					x								3	3
Dengue	21								x					x		2	2
Mottled enamel					x	x										1	2
Smallpox	1	x														1	1
Dysentery	7													x		1	1
Tularemia	15			x												1	1
Diphtheria	20														x	1	1
Sprue						x										1	1
Pernicious anemia								x								1	1
Benzol poisoning												x				1	1
Streptococcal group														x		1	1
Cancer							x									1	1
Coronary artery							x									1	1
Epidemic jaundice	16														x	1	0

*Note: Other diseases on Dr. Dunnahoo's list in order of rank: Typhoid (8), Poliomyelitis (9), Cerebrospinal meningitis (10), Influenza (11), Plague in rodents (18), Scarlet fever (19), Echinococcosis (23), Gastroenteritis (24), Mumps (25).

Fig 2.4. The tallied list of diseases voted on by attendees of the conference. Across the top are the names of fifteen medical scientists included in the vote. The diseases are listed on the left. The top ten diseases were provided to the Medical Steering Committee for guidance.[x]

Surgeon General's Office of the U.S. Army described the medical, health, and sanitary surveys being conducted in 200 areas in all parts of the world. And Dr. Dunahoo, Chairman of the Interdepartmental Quarantine Commission of the U.S. Public Health Service, had records 20 years back on cholera, typhus, plague and other diseases.[xi]

In light of the situation created by the war, the list of diseases voted on by those at the conference represented five types of diseases, both infectious and non-infectious, important to civilian and military government occupied areas and the public health of the United States. Cholera, malaria, plague, and yellow fever were given high priority for their widespread affliction. Transmissible from man to man via insect vectors or animal reservoirs, the incidence of these diseases was known to have tremendous geographic variation due to cultural conditions, standards of living, and seasonal changes. The typhus group (ie: typhoid fever), transmitted primarily though contaminated food and water, was highly infectious and posed a threat because it was easily disseminated by airplanes. Deficiency and modern nutritional diseases such as goiter, beriberi and pellagra, were known to have a connection with different types of soil and agricultural production. Filariasis and schistosomiasis were both caused by parasites that also were connected with factors of the physical environment. Encephalitis had recently emerged in urban areas of the United States (St. Louis Epidemic of 1933) and was a global threat because of the wide range of animal and insect reservoirs.[xii]

The atlas represented a global scope of disease. Although the atlas included diseases of public health interest to the United States, diseases such as cancer and coronary artery disease that were large causes of mortality in the west were only voted on once at the conference. As early as the 1930s clusters of cancer were identified in New York, New

Jersey, Maryland, Massachusetts, and Connecticut (Shannon and Pyle 1993). However it was not until the 1970s that epidemiological studies began to describe cancer as having environmental and behavioral risk factors (Doll and Preto 1981). Mortality rates provided by country census were the dominant source of statistics until the development of the first 100 cancer registries by the World Health Organization in the 1950s (Wagner 1985). The National Cancer Institute's Surveillance, Epidemiology, and End Results Program (SEER) developed the first US national cancer registry in the mid 1970s. The absence of interest in these diseases suggest perhaps there was not enough information regarding relationships of disease with the natural environment, there was no evidence of geographic variation at the global level, or given the high mortality rates due to infectious diseases acquired by military men worldwide, mortality due to cancer seemed of relatively low priority.

A Cartographic Analysis

J.K. Wright presented the cartographic considerations of the atlas. Wright had been director of the AGS since 1938, succeeding Isaiah Bowman (he continued as director until 1959), and was an expert in mapping population distributions. He was particularly interested in overcoming the geographic limitations of mapping population by the districts in which people lived. The Census was the primary data source for Wright's earlier studies of population, which he used to create a dasymetric map, a technique that overcame the limitations of the standard area based mapping technique seen with the choropleth. Using Cape Cod as an example, Wright painted a more realistic picture by delineating uninhabited areas from inhabited based on topography and portrayed population as a semi-continuous and semi-disrupted system (Wright 1936). With this knowledge, Wright promoted the careful consideration of area-based disease mapping noting "unless the territorial units with respect to which they are plotted are all equal in area, choropleths indicating absolute quantities pertaining to those units are misleading…(Light 1944 p.650).

> "The better our understanding of environmental conditions that foster the existence and propagation of a disease, the easier it is (a) to combat that disease in areas where it exists, and (b) to recognize other areas having similar environmental conditions into which there is a possibility or a danger of the disease's spreading." Wright, 1944[xiii]

There were two types of facts that needed to be combined to illustrate the primary purpose of the atlas. First, the forms of distributional patterns themselves needed to be represented, as well as the relationship of the distributional pattern to the physical, biological, and human environment. The most difficult problem facing Wright regarding the distribution of diseases was the selection "of individual conditions and combinations of conditions that were most critical and most readily susceptible of cartographic representation."[xiv] He had recently published an article in the *Geographical Review* entitled "Map Makers are Human: Comments on the Subjective in Maps" (Wright 1942). Through processes of simplification and amplification, Wright knew the reliability of the quantitative information included on a map relied heavily on the judgment of the cartographer. "The trim, precise, and clean-cut appearance that a well drawn map presents lends it an air of scientific authenticity that may or may not be deserved" (Wright 1942). In the article Wright reviewed in depth what symbols best represented 'locational quantities' and 'spatial quantities' and recognized spatial data such as populations collected via the census were bound by political divisions he generally referred to as control spaces.

In similar form to the publication, Wright systematically approached issues of scale, data representation, and cartographic techniques for showing correlation.

Wright knew mapping disease distributions would require maps of different scales, but which scale would best represent certain diseases? Maps of small, medium, and large scales were labeled to bring out the macrogeographical (world distribution), mesogeographical (continent or country distribution), and microgeographical (city distribution) characters of disease, respectively. "The micro characteristics that are typical of malaria in one part of the world may differ greatly from those typical of another. For such diseases a single micro map would be misleading." These terms were not recognized technical terms in geography, but were merely used as convenient labels.[xv] Light did not like the idea of restricting geography to terms such as micro and macro geography. 'Just talk about the geography of disease, meaning, its response to environment at whatever plane.'[xvi]

Wright presented the symbols available for mapping to the conference in the form of a table (Figure 2.5). The symbols were classified according to the nature of the symbols themselves and the nature of information provided by the symbol. In the left axis of the table, symbols were divided into point symbols, line symbols, and areal symbols. The columns described the symbols as either qualitative "for difference in kind only" or quantitative "for differences in degree as well as in kind." Wright provided examples for the absolute and functional applications that he considered suitable and unsuitable for showing quantities (Light 1944). Wright discussed distributional patterns as either qualitative or quantitative. He described qualitative symbols as 'self- explanatory' to

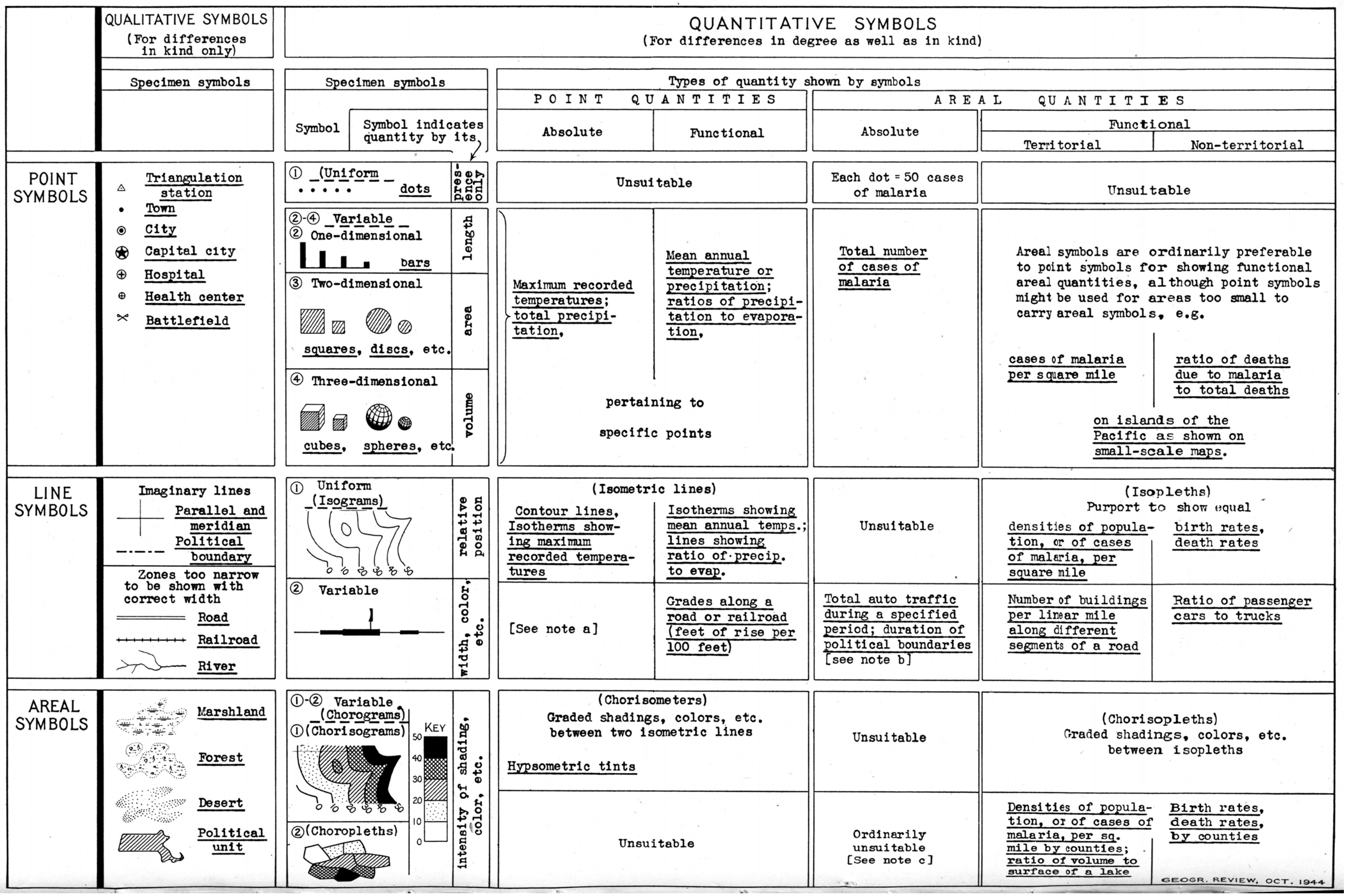


Figure 2.5. A summary of cartographic considerations for the Atlas of Diseases. Published in "A Proposed Atlas of Diseases" in the Geographical Review, October 1944.

represent facts such as 'routes of movement…areas where it [disease] is epidemic… the extent of disease on a particular date…' or 'as reported between two selected dates.' Quantitative facts were described as 'those that shed light on the intensity of occurrence' such as 'the total number of cases (deaths), frequency of epidemics and a variety of ratios, as for example, that of the number of cases to the total population, deaths to cases, cases to population in particular age groups."[xvii] Quantities indicated by area symbols were further described as either territorial or non-territorial to differentiate between the function of area in terms of acres, square miles, etc and when the 'size of the area does not constitute the function.' "The density of a population…in a county is a territorial functional quantity, whereas the birth rate in the county (number of births per annum per 1000 inhabitants) is a non-territorial functional quantity (Light 1944 p.650)."

On the practical side, Wright was aware of the complexities of data gathering. Since it was not feasible to conduct field surveys, the maps were based on (a) existing maps (Figure 2.6), (b) statistical data aggregated by areal units, (c) non-statistical data gathered from publications, and (d) the experiences and first-hand knowledge of medical and public health authorities on the conditions in particular areas.[xviii] Wright had visited Col. Anderson at the Surgeon General's office and had seen the card catalogs and large maps of the world that held a wealth of information on the geographical conditions connected with disease (ie: water supply, drainage), insects and animals bearing disease, nature of the diseases themselves, and the organization of sanitary services such as hospitals, the number of bed in each, and statistical material.[xix] Figure 2.6 is an example of one of the maps produced by the Surgeon General's Office of the U.S. Army Wright may

Malaria

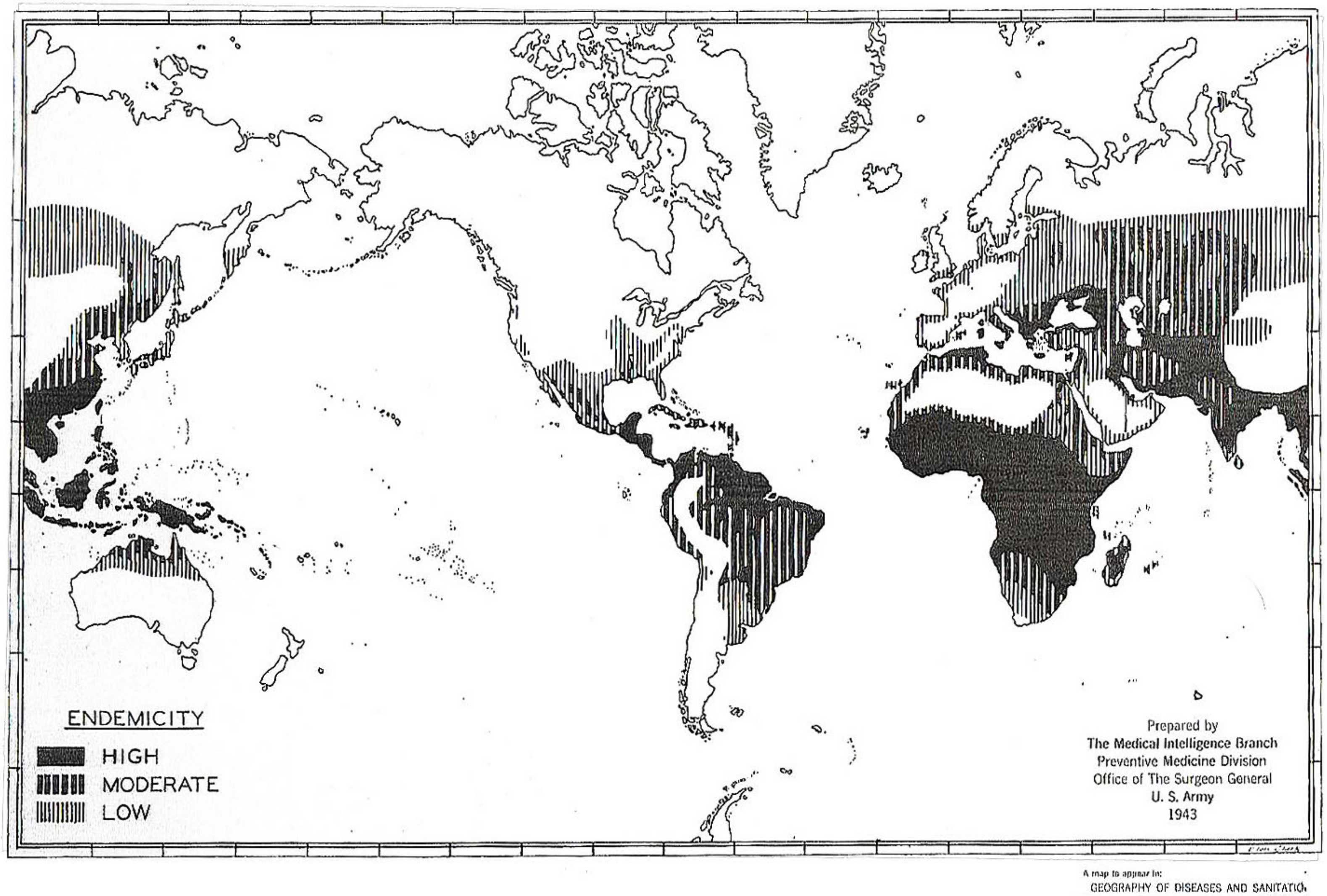


Figure 2.6. A Malaria medical map prepared by the Medical Intelligence Branch, Preventative Medicine Division, Office of The Surgeon General, U.S. Army, 1943. A map to appear in 'Geography of Diseases and Sanitation in Tropical and Subtropical Regions."[xviii]

have collected to provide data for a brief analysis of the general geographical features of disease.

> "In an atlas dealing with distributions, such as those of diseases, the characteristic most desirable in the projection is that areas be show equivalently" O.M. Miller (Light 1944 p. 649).

William Briesemeister, the senior cartographer for the AGS, designed the base map used in the *Atlas of Diseases* with the guidance of O.M. Miller, senior cartographer at the AGS. Seven projections originally drawn for and kept by Ginn and Company, an educational publishing group headquartered in New York, were received by the AGS and used with the companies' permission.[xix] Briesemeister designed a standard base map that projected areas equally. The final base map was inspired by the oblique Mollweide and Hammer-Aitoff projections that were useful in plotting world distributions. The final projection used in the *Atlas of Diseases* was graphically constructed to reduce the shape distortion of the major landmasses of Eurasia and North America. There are no breaks in the continuity of major landmasses and the Arctic Sea is seen without interruption (Briesemeister 1953). Alternative projections were selected for the atlas when the standard base map was not adequate to emphasize particular positional relationships (Light 1944). For example, the Albers conical equal-area projection was used for mapping the prevalence of cholera in Southeast Asia at a scale of 1:20,000,000 (May 1951). An azimuthal equal-area projection was used to map mosquito distributions across Africa at a scale of 1:35,000,000 (May 1951).

Dr. Redmond, President of the AGS and chairman of the meeting concluded the purpose of the atlas was primarily for research, rather than textbook or popular use. The atlas was published on separate pages as soon as sections were available. If medical data were not readily available or could not be assembled in a considerable amount of time, maps representing the over-all picture of geographical factors related to disease were issued. Revisions of the maps were published as significant new data became available (Wright 1944).

The interest in producing the *Atlas of Diseases* led Wright to “invent” thematic mapping a second time (Crampton 2004). Techniques such as the choropleth, developed in the 1850s, were redefined in Wright’s table and categorized according to the qualitative or quantitative nature of the data the points, lines, or areas represented. The development of the atlas and the development of Wright’s table resulted in the scientific formalization of cartographic terms still used today. Wright’s cartographic considerations also represent a mapping process by which knowledge was gained about particular places with disease, a knowledge defined by the natural and social environments that correlated with disease, not by the political boundaries in which people lived.

The Steering Committee

The first steering committee was held on September 22, 1944.[xx] The Committee used the list of diseases provided by the medical scientists at the Conference three months earlier to discuss the types of maps most appropriate for showing factors that affected various diseases such as population, topography, fauna and flora, and climate. The committee was familiar with associations between cholera and migration, exploration, and transportation as seen with the Suez Canal. The Committee agreed that it might be necessary in some instances to map economic status or the distribution of forests as opposed to open areas or temperature. Unable to outline a distinct set of guidelines, the committee decided a pilot study was in order. The Committee voted on two pilot projects, one on cholera in the Delta region of the Ganges River in the Hunan Province of China and one on fluorosis in the United States.[xxi] Only one project made it to publication.

The Pilot Study

Dr. H. Trendly Dean, a senior dental surgeon from the National Institute of Public Health and the United States Public Health Service in Washington D.C. was contacted to direct the fluorine study. Dr. JK Wright wrote to him stating "the purpose of the fluorine study is to show a start actually made in the study of diseases in relation to the geographic environment, show a study capable of doing worthwhile work along these lines, and provide sufficient evidence to raise funds for further work on the atlas."[xxii] It was only 15 years previously in the early 1930s that small amounts of fluorine in the drinking water had been recognized as beneficial to dental health. Public health interests were concerned with the dangers of excess fluorine such as chronic fluorine poisoning, enlarged thyroid gland, development of high blood pressure and fragile bones.

Of great importance to the AGS was the use of "standard and special cartographical techniques as analytical tools (Van Burkalow 1946)." Anastasia Van Burkalow was the lead scientist on the pilot study "Fluorine in United States Water Supplies." The pilot study was the model modern science would follow to study the influence of the environment on health and disease. The purpose of her study was to focus on methods of research used to show the correlation of the excess or deficiency of fluorine in the drinking water with 'water-bearing layers from which they are derived (Van Burkalow 1946). When necessary, Von Burkalow relied on Wright's cartographic guidance when faced with the challenges of mapping incomplete data sets and representing variations in fluorine content at the local scale.[xxiii]

The data was presented on 7 maps, 4 choropleths, 2 isopleths, and one dot map. The recent interest in fluorine content meant that there was limited literature and data available. Fluorine content had never been studied before so the first choropleth map was made to see just where data was available across the country. Von Burkalow recognized that shading the entire area of the county to represent a maximum value could be misleading. Mapping one value for each county could not clearly represent the local and regional variations of fluorine content that resulted from the variations in sedimentary rock that released the fluorine. To ensure this point was clear, she included two isoline maps of North Dakota. One map shows all known fluorine values and the other shows only the maximum fluorine values(Figure 2.7) (Van Burkalow 1946).

> "The article emphasizes certain features held to be essential to a modern scientific study of the influence of environment on health and disease: concentration on one or a very few factors; review of the medical evidence on which the etiological connection is based; and a geographical study in which the relative reliability of the evidence is appraised, the distribution of the pertinent factor studied, and the basic environmental conditions which determine that factor analyzed and explained." Richard U Light (Van Burkalow 1946 p.193)

In the end, the pilot study accomplished what the steering committee set out to do. Van Burkalow's study was evidence that it was possible to develop a geographic study using maps to acquire knowledge about disease as well as using maps as analytic tools to correlate disease with the natural environment. The process was not accomplished with the construction of one single map, but rather a number of maps and map types were involved. It was not until two years later that progress was made in establishing a program of medical geography.

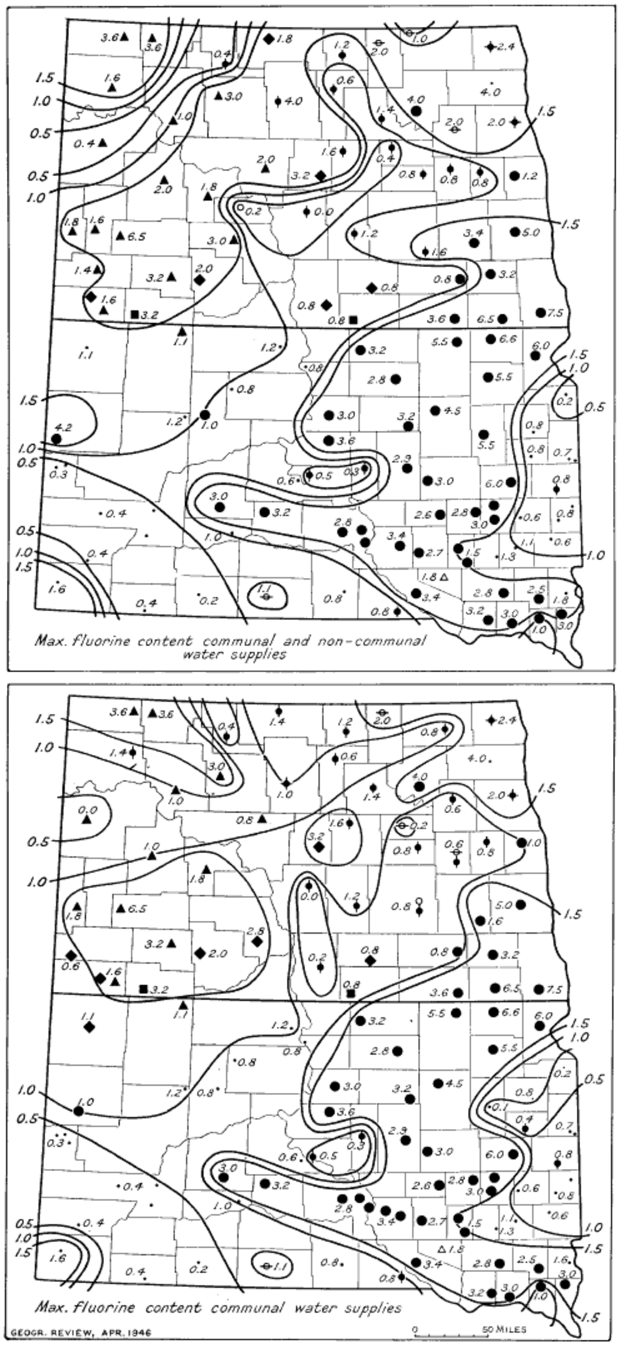


Figure 2.7 Isoline maps included in Von Burkalow's "Fluorine in United States Water Supplies: A pilot study for the *Atlas of Diseases*" published in the *Geographical Review*, April 1946. One map shows all known fluorine values and the other shows only the maximum fluorine values.

Progress in Medical Geography

In 1948 Light began his search for someone to direct the *Atlas of Diseases*, or "Studies in Medical Geography" as Light thought the title should be.[xxiv] After months of searching, Light received a letter from Jacques May coupled with an introductory letter from Dr. HE Meleney of the New York School of Medicine (Wright 1952). Eight letters of recommendation later, May accepted the position of directing and establishing a Department of Medical Geography at the AGS for $20,000 a year.

Although May did not officially accept the position until Nov 12, 1948, he had produced a report "Note on an Atlas of Diseases" two months earlier. May's medical experience in Malaya, Burma, China, Africa, and England as a member of the French Colonial Service prompted him to compare and study the responses to medical practice in the tropics to those of France. This foundation of knowledge led him to recognize that "The geographical aspect of medicine appeared to be worth more attention than had been hitherto given judging by the medical literature."[xxv]

May recognized the atlas as the primary method for recording present knowledge of medical geography. Dr. May's outlined the basis, purpose, and methods of the 'new science' on the basis that medical geography would be a 'census of known facts.' The census was a work in progress, represented present knowledge on facts of pathology and geography, and provided a framework for continued research. May's purpose for studies in geographical medicine was "to learn how to read the vast amount of experimentation – on a scale which no man could produce in his laboratory" and "to establish working hypotheses for further research which would throw new lights on biology and pathology." "The methods and tools by which present knowledge in these fields could be recorded could be an *Atlas of Diseases*." [xxvi]

May wanted the map-reader to be informed. He planned the atlas as a 'continuous publication of successive issues' and with an average of two issues a year, within 5 years, 20 diseases could be surveyed. He suggested ranking the sources on a scale of 1 to 5 where 5 represented the most reliable source, such as those from the League of Nations or the World Health Organization. Making a distinction between the more reliable and less reliable sources, May stated, "Thus informed, the reader would draw his own conclusions." [xxvii] (May's ranking system was never published)

In addition to the atlas, May developed other studies in medical geography. The "Caribbean Project" was designed with the objective to present the "correlations between the actual distribution of disease as revealed by the medical and statistical survey and the picture revealed by the mapping of geogens (or geographical factors)." The study represented the fist attempt at calculating the prevalence of disease. The first problem to be solved in medical geography, May stated, "is the method of gathering accurate data on the distribution of diseases, pathogens, and geogens (or geographical factors)." The Caribbean region was chosen as study site because the geographical boundaries correspond to the political boundaries, few variables due to immigration and emigration, the region had a health and statistical agency of their own, and there was a wealth of information regarding a variety of diseases. May wanted to know, under these circumstances, how the findings compared with results acquired from the present method of reporting and notification he regarded as 'grossly inaccurate.' [xxviii]

May published a list of geographical factors known to have correlations with disease and established the methods and objectives of medical geography. In his discussion of how disease results from parasitic infection, May discussed elements of the climate, water supply, soil type, and culture to illustrate the interrelationships of various pathological and geographical elements contributing to disease. May's tabulated the two, three, and four factor complexes of disease, marking the first attempt at a 'census of our present knowledge of medical geography (May 1950).'

The World Distribution of Cholera – A cartographic analysis

The "World Distribution of Cholera" was the second plate of the *Atlas of Diseases* published in the *Geographical Review* (Figure 2.8) (May 1951). Cholera is caused by the virus *Vibrio cholerae* and is favored in areas with high temperature, high humidity, and precipitation. In addition to a short review of epidemiology, a map using multiple scales and multiple types of data representation illustrating the correlation of disease with the natural and social environment was published. One large elliptical world map, six-satellite world maps, three meso-scale maps of the Southeast Asia region, and a series of country-level maps of India were all contained within the limits of a 95 x 63.5 cm of space. Cholera was linked to factors of economic geography, physical geography, and human geography. Combinations of qualitative and quantitative symbols were used to illustrate these links.

The main map shows the major routes of the first pandemics. The correlation of disease with the routes of commerce by ships, railroads, or caravans are represented using four lines of different color where each line corresponds to the years 1816-1823, 1826-

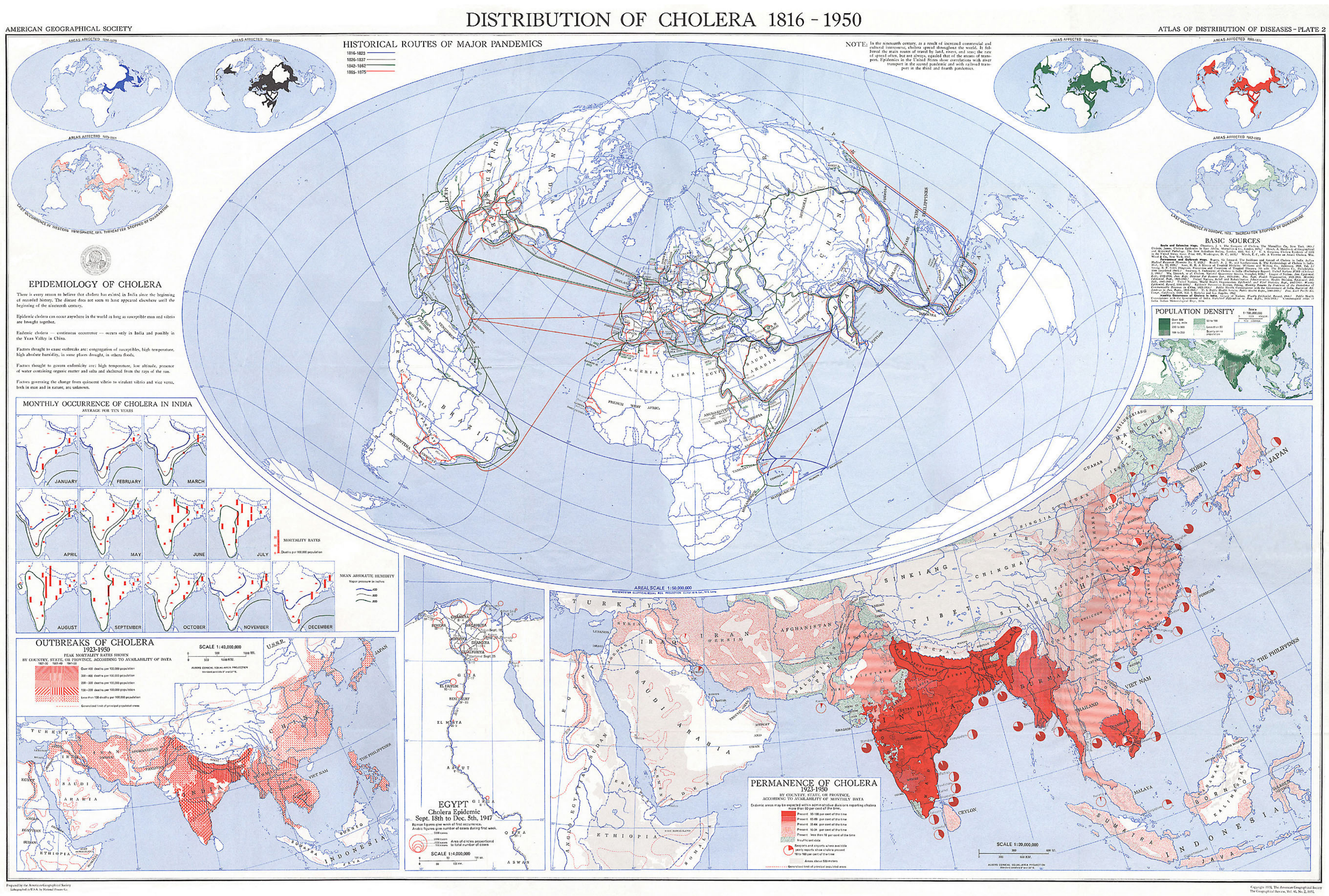


Figure 2.8 World Distribution of Cholera 1815-1950 “In the nineteenth century, as a result of increased commercial and cultural intercourse, cholera spread throughout the world. It followed the main routes of travel by land, rivers, and seas; the rate of spread often, but not always, equaled that of the means of transport. Epidemics in the United States show correlations with river transport in the second pandemic and with railroad transport in the third and fourth pandemics.” (Note printed on the Distribution of Cholera 1816-1950)

1837, 1842-1862, and 1865-1875, respectively. The blue line represents the origins of the first pandemic when from 1817 1826 cholera spread along land and sea routes from Burma and India to China, Bangkok, and Japan. Cholera reached as far as Eastern Africa and Eastern Europe as commerce directed ships across the Indian Ocean south to Mauritius and west to the Persian Gulf and Euphrates River. The second pandemic began in 1826 when cholera crossed the Wall of China into Mongolia and eventually spread to Moscow via caravan routes into Russia. Cholera immediately spread throughout Western Europe and by the third pandemic had spread to the Americas. Cholera continued to spread around the world during the forth pandemic in 1865-1875 as commerce and trade continued along the routes between Europe and Africa, Europe and the Americas, and Europe and Southeast Asia.

Six satellite maps around the main map show the areas affected by the various pandemics. According to this series of maps, the first known pandemics of cholera occurred in India, Thailand and the South Pacific region, and extended as far north as the eastern coast of China permitted. From 1823 – 1912, cholera spread through out Europe, NE Africa, Central America, and some coastal areas of North and South America via the major routes of commerce. The last pandemic ended for Europe in 1923 after quarantines were established. The only known epidemic outside of Asia after 1923 occurred in Egypt in 1947 and is presented on a large-scale map at the bottom of the page. Proportional circles are used to show the total number of cases along the Nile. The greatest number of cases is seen closest to the Mediterranean coast (May 1951).

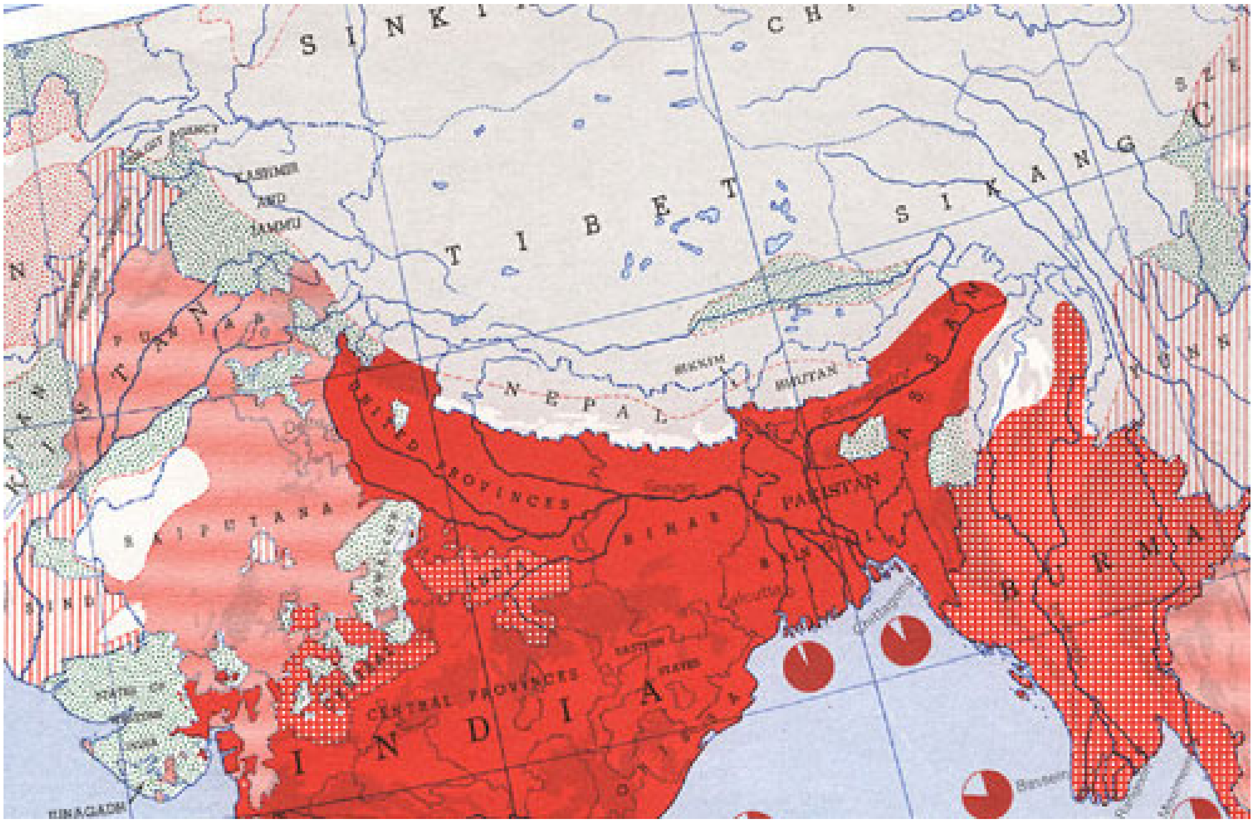
Epidemics of cholera were not only associated with the social environment. Outbreaks were also linked to the onset of rainy seasons, high temperatures and high humidity. The monthly occurrence of cholera in India is shown to the left of the main map using proportional bars to represent the mortality rates per 100,000 averaged over ten years for in the 15 provinces of India. To show a correlation with the natural environment, isolines were drawn to show the change in absolute vapor pressure that occurred from month to month. According to these maps, mortality rates were highest during the summer months of June, July, and August when vapor pressure was at it's highest, as was the temperature (May 1951).

Factors associated with human geography contributed to the permanence of cholera in India, SE Asia, and the Pacific. Epidemic cholera, otherwise referred to as 'occasional' cholera, was linked to population density and movements of large masses of people. Outbreaks of cholera, 1923 – 1950, were mapped with data available by country, state, or province. A 3 x 5 matrix of shading and texture was used to demarcate peak mortality rates measured in deaths per 100,000 population over three decades. Areas of darker shading suggested repeat outbreaks over the years. Similarly, the permanence of cholera 1923-1950, also based on available reports by country, state, or province, was based on the percentage of time, usually months, in which presence of cholera was reported. The darker the shaded texture of red, the greater the percentage of cholera reports. Cholera was reported 90 to 100% of the time in India and Pakistan and 65-80% of the time in Burma and Cambodia. Cholera advanced more quickly when faster means of transportation were introduced. Thus, a circle is colored in according to represent the percentage of positive reports collected from major sea and airports on an annual basis (a half circle equals cholera reported 50 % of the time or six months out of the year). Elevations of 500m and above were shaded in gray for the convenience of the map-reader (May 1951).

Discussion

The two maps of cholera outbreaks and permanence show evidence of Wright's 'chorisogram' (Figure 2. 9). The chorisogram was constructed similarly to the dasymetric map by shading areas bounded by an isogram, or 'quantitative line symbols representing quantities assumed to be constant along the whole length of each line…. with respect to phenomena such as altitude, etc (Light 1944).' The prefix 'chor' meaning area or place distinguishes the shading of areas using varied textures of the same color from the isopleth technique that uses uniform line symbols to represent constant values of numbers. Most notably, the data were not limited to the political boundaries of each country, district, or province. As noted on the legends of both the map of outbreaks and permanence of cholera, the principal limits of the population were demarcated with a red dotted line. Looking closely at the border of India and Nepal, the placement of the dotted line indicates the population extends almost to the northern border of Nepal, whereas cholera is limited to southern half of Nepal. Similarly, in Iran and Afghanistan, the permanence of cholera is only shown in the areas where the population lives, which happens, in these countries, to occur at elevations below 500m. The population density map of the same region found on the right uses the same technique of only shading the principal areas, not the entire state, province, or country as seen with choropleths (May 1951).

Wright's table and definitions of cartographic terms outlined a number of map types suitable for mapping disease and standardized the considerations for quantitative mapping. Wright's contribution is twofold. First, Wright laid the framework within which geographers could easily adopt conceptions of space as points, lines, and areas. Arthur Robinson's included a copy of Wright's table in his textbook, *Elements of Cartography*.



------ Generalized limit of the principal populated places

Figure 2.9 Wright’s chorisogram showing the principal limits of the population.

The table was included in subsequent editions published as late as 1960 (Robinson 1953; Robinson 1960). Today, these concepts of space have been adapted to accommodate modernizations in mapping such as computer technology. Wright's conception of geographic space as points, lines, and areas has since been used as the basis of points, vectors, and polygons by software such as GIS (Crampton 2004).

Wright's second contribution is his commitment to presenting the most geographically accurate picture of the phenomena at hand. Wright's experience in population mapping taught him that administrative borders do not define the characteristics of a population, nor does it define phenomena associated with populations, such as disease. The atlas' use of the 'chorisogram,' perhaps Wright's translation of the dasymetric, demanded geographers and cartographers know something about the areas being mapped. Although most of the data collected for the atlas was collected at the country, state, or province level, Wright avoided misleading the representation of areal data to the best of his ability by using the chorisogram technique to illustrate how disease and the natural and social environment interacted.

The maps were recognized as an important contribution because for the first time, it was possible to see at a glance, areas in which certain diseases occurred. The studies in human starvation even made headlines in the New York Times announcing, "American Geographical Society finds two-thirds of humans eat foods lacking in energy (Anonymous 1953)". In October 1950 medical professionals nationwide received a letter from the AGS accompanied by a complimentary map of the "World Distribution of Poliomyelitis." Compiled from hundreds of sources, the maps were used for epidemiological exercises at Yale University School of Medicine and Harvard University's School of Public Health among others. Saul Jarcho was "amazed at the amount of valuable information which has been compressed into the limited area available without damage to the agreeable general effect.[xxx] The scope of the data assembled in cartographic form saved the user many hours of searching through the literature.[xxxi] In fact the maps were so popular, that over 60,000 copies were sold or distributed.[xxxii] The most copies sold were maps on polio, cholera, and dengue fever.

The atlas is the first series of statistical maps of disease published by the AGS and it brought together developments in several areas that were necessary for the atlas to be produced. First, there was an interest in studying the geographical relationships of disease. Secondly, the global extent of World War II expanded medical geographic knowledge, particularly in regions where U.S. soldiers were at greatest risk for disease. And thirdly, there was a need to standardize the cartographic representation of statistics. The achievements of the atlas have shaped geographic thought about disease.

The primary responsibility of the Department's director, Jacques M. May, was to head up the atlas and promote studies in medical geography. May remained head of the program until July 1957 when the financial support provided by the Upjohn Pharmaceutical Company, the AGS, and the Office of Naval Research came to an end. May continued to contribute to the literature of medical geography becoming one of the foremost experts in studies on the ecology of disease. He published a ten volume series of books in 1961 entitled the *Ecology of Malnutrition in the Far and Near East* (May 1961) and the *Ecology of Malnutrition n West and South America* (May 1974). Each book covers a different region of the world presenting discussions on the interrelationships between geography, climate, history, government, agricultural policies, and foreign aid and the subsequent impacts on food resources, industries, supplies, diets, and nutritional disease patterns (May 1961; May

1974). May continued to carry out field investigations in third world countries until a fateful automobile accident took his and his wife's life in 1975 (Koelsch 2003).

In addition to the revived interest of the AGS, studies in the climatic, biological, social, and cultural processes that govern the occurrence of disease were implemented in many international arenas. The same year May began his work at the AGS, the World Health Organization was formed to address global issues of health. In 1949, the International Geographical Union appointed an international Commission on Medical Geography. European pathologists revived the International Society of Geographical Pathology in 1952, 20 years after its presumed extinction. The International Society of Bioclimatology and Biometerology representing twenty-four nations was established to form relationships between researchers in various fields of medicine. And even another atlas was in the works, this time headed by German professors in Heidelberg and based on studies 'pushed ahead during World War II for military reasons.'[xxxiii]

Summary

Following the chronological development of the atlas including who was involved and why they wanted to produce the maps, the atlas is presented as a case study to understand how mapping shaped geographic knowledge about disease. The development of the atlas is discussed in the context of World War II and the influence the war had on reviving new interests in medical geography. Planning the atlas prompted the establishment of a Department of Medical Geography at the AGS, the systematic use of cartographic terms, and prioritized the understanding the relationship between the natural and social environment and disease as a global issue. This case study takes a look at the achievements of the atlas as a classic and important initiative in history.

The *Atlas of Diseases* represented a global view of disease and the implementation of a variety of techniques to map medical geographic knowledge about disease. Since the 1950s maps and mapping have changed. Maps are dynamic representations that historically were considered elements of communication. Until the 1980s and 1990s, maps represented a scientific, objective presentation of known information (MacEachren 1995). The scientific approach considered maps to be functional (ie: location maps, topographic maps) limited knowledge to what the cartographer thought was important to present. With the advent of computer technology, new roles for maps have developed.

Today mapping acknowledges a difference between exploration and communication. Geographic visualization (GVis) is the term that encompasses and erodes the boundaries between maps as static elements of presentation and maps as dynamic tools of analytic research. The broad range of mapping applications across many disciplines, including public health, is met with a theoretical framework that promotes a more user-oriented, exploratory role of maps (DiBiase 1990; MacEachren 1995). MacEachren's model of Cartography Cubed (C^3) illustrates how maps are no longer seen as static displays of geographic space but rather dynamic tools that go beyond information presentation (MacEachren and Kraak, 2000).

The next chapter uses a content analysis to look at the types of maps found in public health literature today. If the atlas represented a governance of populations based on diseases that correlate with the natural and social environment, what types of diseases are being mapped today and how is mapping disease an act of governance? What types of maps are most commonly used in public health and what are the political implications of these map types?

Chapter 3. Introduction to a Content Analysis

The purpose of the content analysis is to understand the political implications of map types published in the public health literature today. Although disease mapping has been practiced for hundreds of years, the ubiquity of GIS in public health in recent years has increased the availability and interest in the exploration of disease over time and space. Following Foucault's concept of governmentality, geographic and political rationale behind disease mapping was discussed in the cartographic analysis of the *Atlas of Diseases.* Three developments were necessary for its production. First the AGS was interested in developing studies in medical geography. Secondly, the availability of medical data and geopolitical interests in particular regions of the world impacted the types of diseases chosen for the atlas. And finally, cartographic interests resulted in the development of new techniques such as the chorisogram to represent the correlation of disease with the natural and social environment. Today, the US is not at war, however there is continuing interest in GIS applications in public health. In order to understand discuss the political implications of disease mapping today, this chapter review the public health and GIS literature for the most common map types and disease types published in the last four years.

In this study, one cartography journal, three public health journals, one public health newsletter, one health geographic journal, and one interdisciplinary journal are analyzed for map content. *Cartography and Geographic Information Science (CaGIS)*, a journal published quarterly by the American Congress on Surveying and Mapping (ACSM), was selected as the primary cartographic journal. Content analysis of this journal provides base line information for the number of maps recognized in the literature by leading cartographers. The primary academic public health journals include the *American Journal of Public Health (AJPH), Annals of Epidemiology (AEP), and the American Journal of Epidemiology (AJE)*. These peer-reviewed journals are published monthly and are selected for their high Impact Factor, or the measure of frequency with which the "average article" in a journal has been sited in a particular year (ISI 2002). In an effort to include public health and GIS considerations of the literature, citation counts were also collected from the bibliography of "GIS and Public Health" by Ellen Cromley and Sara McLafferty. These counts also yielded *AJPH* and *AJE* as two highly cited journals. The bimonthly electronic newsletter included in this study is *Public Health GIS News and Information (PHGIS).* Published by the National Center for Health Statistics (NCHS), this publication is chosen for its explicit dedication to the advancement of public health research through the use of GIS. The open-access, peer-reviewed *International Journal of Health Geographics (IJHG),* published by BioMed Central, was also chosen. The exclusive online availability of this journal provides a niche for researchers focused on a variety of interdisciplinary geospatial topics in health/healthcare and optimizes viewing of health geographics. Finally, *Health & Place (H&P)* was selected for its interdisciplinary contributions from medical geography, medical sociology, health policy, public health, and epidemiology to the study of health and health care. This journal was chosen because it targets academics, researchers, students, and policy makers concerned with the geographical impact of health policy. Six of the seven publications including *CaGIS*, *AJPH, AEP, AJE, IJHG*, and *H&P* are peer reviewed.

Methodology

Defining the criteria of this analysis requires consideration of three principle research priorities; public health, GIS and cartography (Table 3.1). The criteria definitions used in this study are adapted from Borden Dent's "Cartography: Thematic Map Design (Dent 1999)" and Ellen Cromley and Sara McLafferty's "GIS and Public Health (Cromley and McLafferty 2002)." These criteria were developed as an attempt to investigate current mapping strategies used in representing health information in the literature and the variation of spatial information that is displayed. Illustrations are included with each definition of map type using examples from each of the journals surveyed in this analysis.

There are a number of techniques cartographers use to show data on a map each with their own set of characteristics. Maps and mapping are a set of tools individual researchers use to explore, analyze, or display a particular set of characteristics. The following is a list of definitions for 18 criteria categorized into three main categories. The first category is map type and includes three subcategories; general-use, thematic, and other maps. These criteria categorize maps based on the types of attributes they represent. Feature, number, or category attributes can be classified into points, lines, areas, or volume. General-purpose maps show all or some of the geographic features at the same time. The categories of base map and location map describe the function of a map to present geographic features in an area and specifically identify the location of a study area, respectively. The projection category is defined to identify the form of a map that specifically relates to the cartographic interest in mathematically translating the three-dimensional surface of the earth to a two-dimensional plane. In contrast, thematic maps show one or two layers of geographic attributes that are often quantified and analyzed for spatial distributions (Clarke 2001). Within these three subcategories, there are eleven criteria defined to encompass the different forms of thematic maps found in the literature.

The second category includes four criteria for specialization area. This category represents four criteria that reflect the variety of pathogens or medical conditions presented in the research. The third category is study design. Three criteria are defined in this category to provide a geographic frame of reference for the population involved in the study. All six publications were analyzed using category one, map type, for issues published in January 2000 – December 2004 with the exception of *IJHG*. This online journal began publication in 2002. The articles of three public health journals *AJPH, AJE, AEP* were analyzed using all three categories; map type, specialization area, and study design.

Table 3. 1 Content analysis criteria definitions.

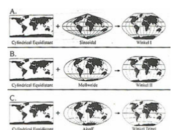
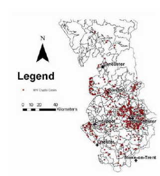
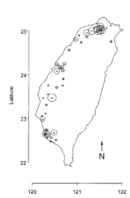
CRITERIA		***DEFINITIONS***
1. MAP TYPES *General – Purpose Maps* Base Map	 (Barnett, Halverson et al. 2000)	A general – purpose map that functions to arrange thematic information to a spatial or geographic frame of reference. Includes multiple forms of maps such as a DEM.
Projections	 (Kessler 2000)	Form of a base map that displays the product of mathematical functions that transform the curved, three-dimensional surface of the earth to a flat, two-dimensional representation.
Location	 (North, Howard et al. 2003)	A thematic mapping technique that functions to qualitatively display the spatial and geographic content of nominal data in the form of points, lines, or polygons.
Thematic Maps Dot map	 (Hughes, Syed et al. 2004)	A form of quantitative thematic mapping that displays the spatial density within an area using point symbols that represent one or more events.
Proportional symbols	 (Hwang and Chan 2002)	A form of quantitative thematic mapping that displays data aggregated at points within an area using a symbol that varies its size in proportion to the quantities it represents.
Choropleth	 (Naleway, Belongia et al. 2002)	A form of quantitative thematic mapping that displays areal data often aggregated and bounded by administrative units.

Table 3.1 Criteria definitions continued.

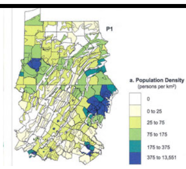
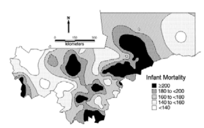
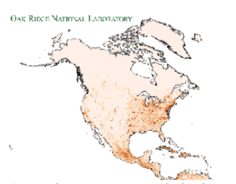
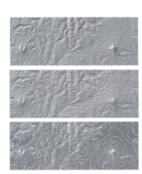
Dasymetric	 (Eicher and Brewer 2001)	A form of quantitative thematic mapping that is similar to the Choropleth technique in that it displays areal data. Rather than administrative units, this technique displays data as a statistical surface with a series of statistically uniform zones.
Isarithmic	 (Gemperli, Vounatsou et al. 2004)	A form of quantitative thematic mapping that displays real or three-dimensional geographical volume with line symbols.
Combination Chor/Dot Chor/Proportional	 (Eschbach, Oster et al. 2004)	A form of quantitative thematic mapping that combines real data with point data.
Other Maps Raster or with raster-like elements	 (LandScan2000 Global Population Database. Oakridge)	A form of mapping that represent spatial and attribute data driven by a model that is based on cells or pixels. A raster map is usually associated with the GIS analysis output of spatial data that may reveal patterns and relationships difficult to visualize using data tables and formulas. Usually produced for private thinking and may require further cartographic design.
Geo-technique	 (Kennelly and Kimerling 2001)	A process that may use one map or a series of maps to illustrate resolution, calculation, etc.

Table 3.1 Criteria definitions continued.

2 SPECIALIZATION AREA		
1		HIV/AIDS and Infectious Diseases
2		Injury/Violence
3		Substance abuse/Mental Health
4		Chronic Disease/Illness/Cancer
5		Access to Healthcare
3. STUDY DESIGN		
Study Period		The length of days, months, or years to conduct research reported in publication.
Sample Size		The total number of data or study participants.
Study Area		The geographic description of study area as urban, rural, and/or suburban.

Results

The cumulative total number of maps appearing in *Annals of Epidemiology, American Journal of Public Health, Public Health GIS News & Information, International Journal of Health Geographics, Health & Place* and *Cartography and Geographic Information Systems* from January 2000 to December 2004 is illustrated in Figure 3.1. After a low rate of publication, the number of maps published annually has continued to increase. The curve prior to 2002 represents the output of five journals. Even though the *International Journal of Health Geographics'* began publication in 2002, only 3 issues were included in the first volume. The jump in numbers seen in 2003 and 2004 is in part evidence of this journal's increase in papers published.

Table 3.2 summarizes the relative importance of the 11 map types over the period covered in the study. A histogram including the total counts of map type by journal is also provided (Figure 3.2). It can be seen that choropleth maps have been the most prevalent map type over all, accounting for almost 35% of the maps published in all the journals. The top four map types account for about 70% of the published maps. Here it can be seen that the cartography journal *CaGIS*, represents 10 of the 11 map types and is responsible for almost half of the total number of maps. Together, *CAGIS, IJHG, PHGIS* account for 85% of the total number of maps.

Table 3.3 summarizes the number of articles by specialization area for the five public health publications. Almost one half of the studies that published a map specialized in chronic disease, illness, or cancer and thirty percent of the studies specialized in HIV/AIDS and infectious diseases. The fewest number of maps were used in the substance

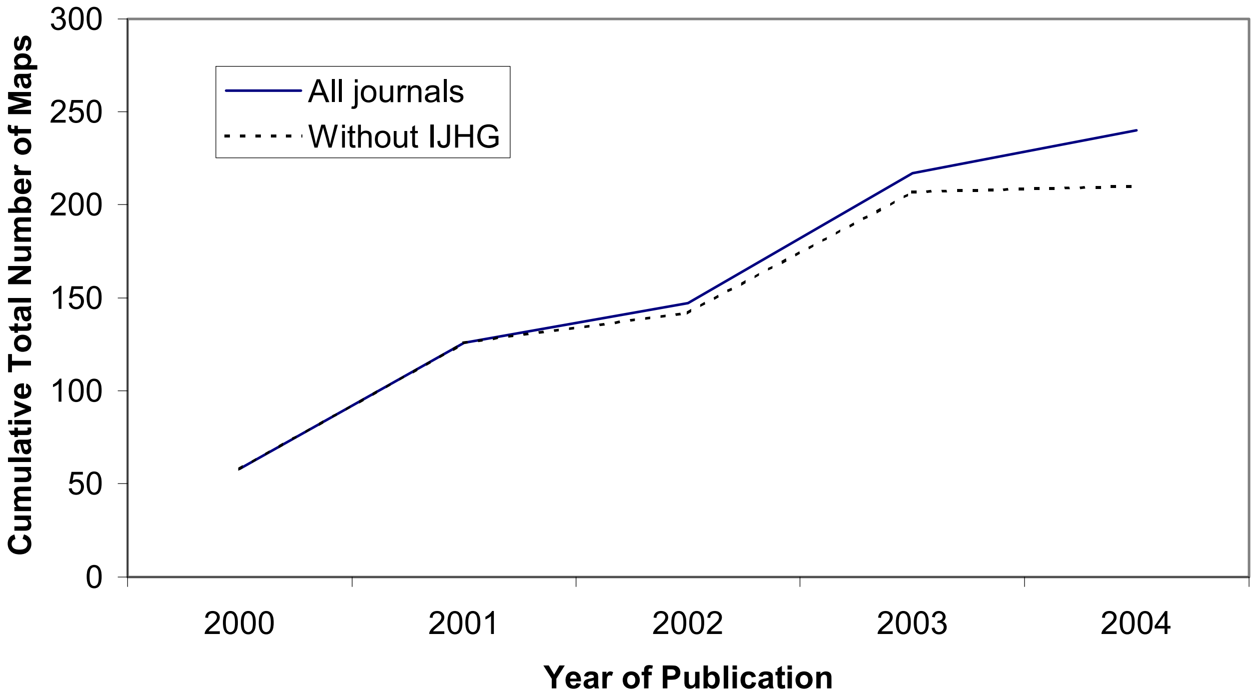


Figure 3.1 Cumulative total number of maps appearing in *Annals of Epidemiology, American Journal of Public Health, Public Health GIS News & Information, International Journal of Health Geographics,* and *Cartography and Geographic Information Systems* from January 2000 to December 2004.

Table 3.2 Total number of maps listed by type.

JOURNAL	*AEP*	*AJPH*	*AJE*	*PHGIS*	*IJHG*	*HP*	*CaGIS*	*Total*
TOTAL MAPS	11	42	45	113	186	136	342	875
Choropleth	4	17	11	46	113	64	44	299
Reference/Location	1	16	16	34	5	44	59	175
Base Map	0	0	0	9	51	0	33	93
Raster or with raster-like elements	2	0	8	7	2	12	62	92
Geo – technique	0	0	0	0	0	5	60	65
Isarithmic	0	0	7	11	4	3	22	47
Projections	0	0	0	0	0	0	38	38
Dot map	3	2	0	1	8	0	8	22
Proportional symbols	1	4	3	2	2	8	2	22
Dasymetric	0	0	0	1	1	0	15	17
Combination – Choro/Dot	0	3	0	2	0	0	0	5

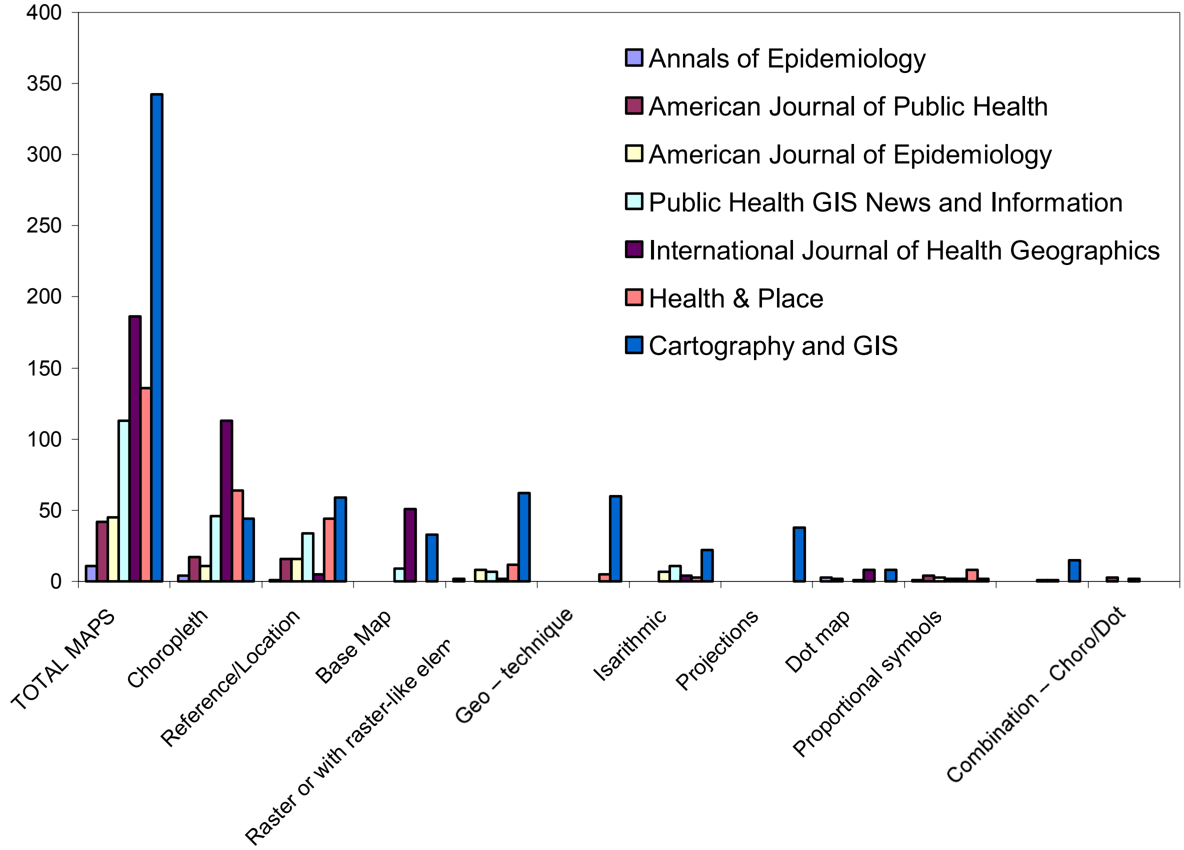


Figure 3.2 A histogram of the total number of maps and map types found in *Annals of Epidemiology, American Journal of Public Health, American Journal of Epidemiology, Public Health GIS News and Information, International Journal of Health Geographics, Health and Place,* and *Cartography and GIS.*

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Table 3.3 Comparison of specialization areas by public health journal.

Specialization Area	*AEP*	*AJPH*	*AJE*	*PHGIS*	*IJHG*	*HP*	*TOTAL*
Chronic Disease/Illness/Cancer	4	10	7	38	21	24	104
HIV/AIDS & Infectious Diseases	0	11	11	20	11	2	55
Access to Healthcare	0	1	0	0	3	16	20
Injury/Violence	1	4	2	1	0	3	10
Substance Abuse/Mental Health	0	3	0	0	2	5	10
Total number of articles	5	29	20	59	37	46	145

abuse/ mental health specialization area. The category chronic disease/illness/cancer is the most self-explanatory category and includes studies of illness due to environmental exposures, morbidity and mortality due to cancer and other conditions, and chronic diseases such as diabetes or asthma. The category, HIV/AIDS and Infectious disease, encompasses diseases transmitted from person to person or via animal and insect reservoirs. The category injury/violence includes issues such as domestic abuse and fetal injury due to prenatal exposure to tobacco. Studies on drug abuse, binge drinking, and schizophrenia are included in the category substance abuse/mental health. And finally, access to healthcare, provides a category for studies of the distribution of health services or primary care physicians.

The total number of articles by journal is less than the total number of maps by journal reported in Table 3.2 and is indicative of the fact that many articles included more than one map. The *AEP*, for example, published eleven maps within 5 articles, an average of almost 2 maps per article. *IJHG* published 186 maps within four articles, an average of almost 5 maps per article. It should be noted here *PHGIS* does not publish the same number of full-length articles as seen in the academic journals. Maps counted from this publication may be included with abstracts and other short reports.

From the articles in the four public health journals, the characteristics of the study design are reported in Table 3.4. Studies that are not included in this table are those that did not present statistical data with a map. In most instances, a base, reference or location map was provided by such studies. Because study samples were reported in whole numbers and in geographic units, it was impossible to calculate an average. Therefore the range is given to illustrate the variability in study size and the capacity of spatial databases

Table 3.4 Comparison of study design characteristics in four public health journals.

Study Design	*AEP*	*AJPH*	*AJE*	*HP*
Study period average in years	2	4	7	7
Sample size range	171 indiv – 399 counties	328 indiv – 47 states	68 indiv – 50 comm	29 indiv – 25 regions
Area: Urban (U) Rural (R) Suburban (S)	1 U 1 R 1 R/S 2 U/R/S	11 U 3 R 2 R/S 11 U/R/S 1 U/S	4 U 9 R 2 U/R, 3 U/R/S 2 U/S	13 U 3 R 4 U/R 18 U/R/S 2 U/S
Total Number of Articles	5	28	20	40

to accommodate large numbers. One study in the *AJPH* used data collected from 47 states. An article in *AJE* mapped data based on 68 individuals. The average number of years and the study area (urban, rural, suburban, or any combination of the 3) are also summarized in this table. A study characterized as U/R/S is indicative that data aggregated to the county, state or country level was analyzed. Otherwise, each study provided a specific description of the study group.

Discussion

Perhaps the most striking relationship revealed by the results is the relationship between map type and specialization area. For example, since the choropleth is the most prevalent map type, it was used to display chronic disease, illness, or cancer data. The choropleth uses distinctive color or shading to depict areally bound data that are often defined by administrative or statistical areas (Dent 1999). Some argue the choropleth is common because it is easy to construct using GIS (Crampton 2004). Others suggest the choropleth is the best suited to represent mortality rates in a form that is familiar to epidemiologists (Brewer and Pickle 2002). The choropleth is technique well understood by geographers and public health researchers and serves as a platform for interdisciplinary discourse on the geographic distribution of disease. However, the over simplification and aggregation of information should be interpreted cautiously with regards to ecologic inference problem (EIP).

The specialization area and type of map published today is an interesting contrast to the specialization area and map type published in the *Atlas of Diseases* 60 years ago. The recent public health literature suggests chronic disease is of greater public health interest than infectious diseases based on the number of papers published on the topic. Although rates of chronic disease and cancer are high in developed societies, infectious diseases such as malaria and tuberculosis still affect large numbers of people in lesser-developed countries around the world. The atlas represented an interest in the global scope of public health whereas public health maps and mapping today represent a more national or statewide interest in disease that is reflected in the mechanisms of data collection, surveillance, and thematic techniques.

Most cancer registries and other databases report chronic disease incidence and/or mortality at the state, county, or SEER level.[1] Choropleths showing health data collected by a more individual means (ie: survey, hospital records, etc) may show smaller geographic units based on mortality rates calculated from population densities aggregated to the census tract or zip code level. Even studies that geocoded individual level data aggregated to some level in order to map a rate. Some studies with this type of data opted to create a dot map illustrating the spatial distribution of the study population in a given area. Mortality rates were not the only type of values that were reported, predictive rates and probabilities were also shown using the various classification schemes offered by the choropleth.

The study period, sample size, and study area can also be dictated by the data source. Maps produced with data conducted in upwards of 10 years collected data from a disease registry/database. Most maps created from a sample size of 5000 or more and/or a geographic unit such as a county or state also collected data from a disease registry/database. And maps including urban, suburban, and rural areas were most likely

[1] SEER is the Surveillance, Epidemiology and End Results, of the National Cancer Institute. SEER collects information on cancers from a statistical sample of the United States population composed of 13 population-based registries representing 14% of the U.S. population.

constructed with data from a disease registry/database. Studies conducted in one of the three areas, either rural, or urban or suburban, were most likely to have small sample sizes.

When compared to other map designs such as the dot map and the isopleth, the choropleth was found to be the easiest for epidemiologists to (1) read an approximate rate from a map, (2) identify clusters of areas with similar rates and regional patterns on the map, and (3) compare patterns across maps by cause, race or sex (Pickle, Mungiole et al. 1999; Brewer and Pickle 2002). Mortality is typically reported as the total number of deaths from disease per year per 1,000 population and is conventionally calculated using population densities collected by the U.S. Census Bureau at an administrative level (state, county, zip code, census tract). Most causes of disease are confounded by age. In a study of lung cancer, for example, it is expected that the majority of cases fall in the upper age brackets. Therefore to account for bias, an age-adjusted rate is computed to standardize the age distribution so that age-composition of the population is no longer a factor. These rates are synonymous with the risk of disease and are a good reflection of incidence rates, or number of new cases, when the case-fatality rate is high and the duration of disease is short (Gordis, 1996).

Epidemiologists are able to make meaning of the data using classification schemes available with choropleth mapping. Quantile classification is easier for epidemiologists to interpret than the Jenks (natural breaks) or equal interval methods used for mapping epidemiological data. Quantile classification usually centers on the median (an indicator of central tendency) and groups the data into classes above and below the median whereas natural breaks and the equal interval methods do not. Mapping age-adjusted mortality rates or disease incidence is meaningful only to other similarly adjusted rates. Therefore, classifying data using the quantile method reflects the ordinal ranking of data making it easier for epidemiologists to read the map (Brewer and Pickle, 2002). Although the familiarity of quantiles should be considered, the exploration of data using other classification schemes may extend the pattern seeking process beyond the limits of statistically calculated averages.

Choropleths depicting health as defined by political units may result in erroneous conclusions if used for policy-making, disease intervention, or treatment. Since the 1930s, mapping a large area has been known to mask the true spatial variation of a population (Wright 1936; Crampton 2004). Mapping cancer incidence, at the state level may for example, depicts large variations occurring at the borders of the contiguous states that does not really exist. The variance in rates is inversely proportional to population size regardless of scale. A small country with a small population, or the census block with the smallest population size tend to exhibit extremely high or extremely low rates of disease (Boscoe and Pickle 2003). In no way can the varied nature of the phenomena being represented be reflected, especially if the area has distinct urban and rural areas. Sales tax percent in a given area is an example where a single value represents an even distribution. The continuous but abrupt nature of this data makes this type of data suitable for choropleth mapping (MacEachren 1994; Crampton 2004). Disease distributions rarely follow pre-defined political boundaries (MacEachren, 1994; Crampton, 2004).

One alternative to the choropleth that is less familiar to public health research is the dasymetric map. Dasymetric mapping was developed in the 19^{th} century and applied by John K. Wright in 1936 as an answer to the choropleth's inability to reveal enough about the population distribution of Cape Cod, Massachusetts (Wright 1936). "A dasymetric map depicts quantitative areal data using boundaries that divide the mapped area into zones of relative homogeneity with the purpose of best portraying the underlying statistical surface (Figure 3.3) (Brewer, MacEachren et al. 1997; Eicher and Brewer 2001)." In other words, dasymetric mapping provides a methodology for refining the spatial unit to create a more realistic estimate of how populations are distributed.

The use of county-level population data to produce a dasymetric map may have potential in public health mapping. As an alternative to pre-defined political boundaries used in choropleth mapping, this type of areal interpolation uses ancillary land-use and census data to create internally homogenous zones. Including the physical environment on a statistical map gives an emphasis of form and if analyzed closely, can provide an understanding of the geographic delineation of people rather than just place names and labels. This process requires knowledge of the place in question and returns to the concept of meaningful spatial zones. A dasymetric is not subject to areal unit-derived problems like ecologic fallacy and the modifiable areal unit problem (MAUP) commonly encountered with choropleths (Openshaw 1984; Eicher and Brewer 2001).

Other geostatistical techniques offer alternatives to area based mapping, each requiring specific data and knowledge of modeling assumptions. Empirical Bayes estimations and kriging are common techniques employed in public health used to interpolate a continuous surface from a discrete set of points (Figure 3.4). Each technique is based on the statistical properties of the data measured and produces prediction surfaces, error surfaces, probability maps and quantile maps that can be used for quantifying spatial patterns, modeling risk surfaces, and assessing relationships between exposure and potential outcomes (Cromley and McLafferty). However the application of these and other

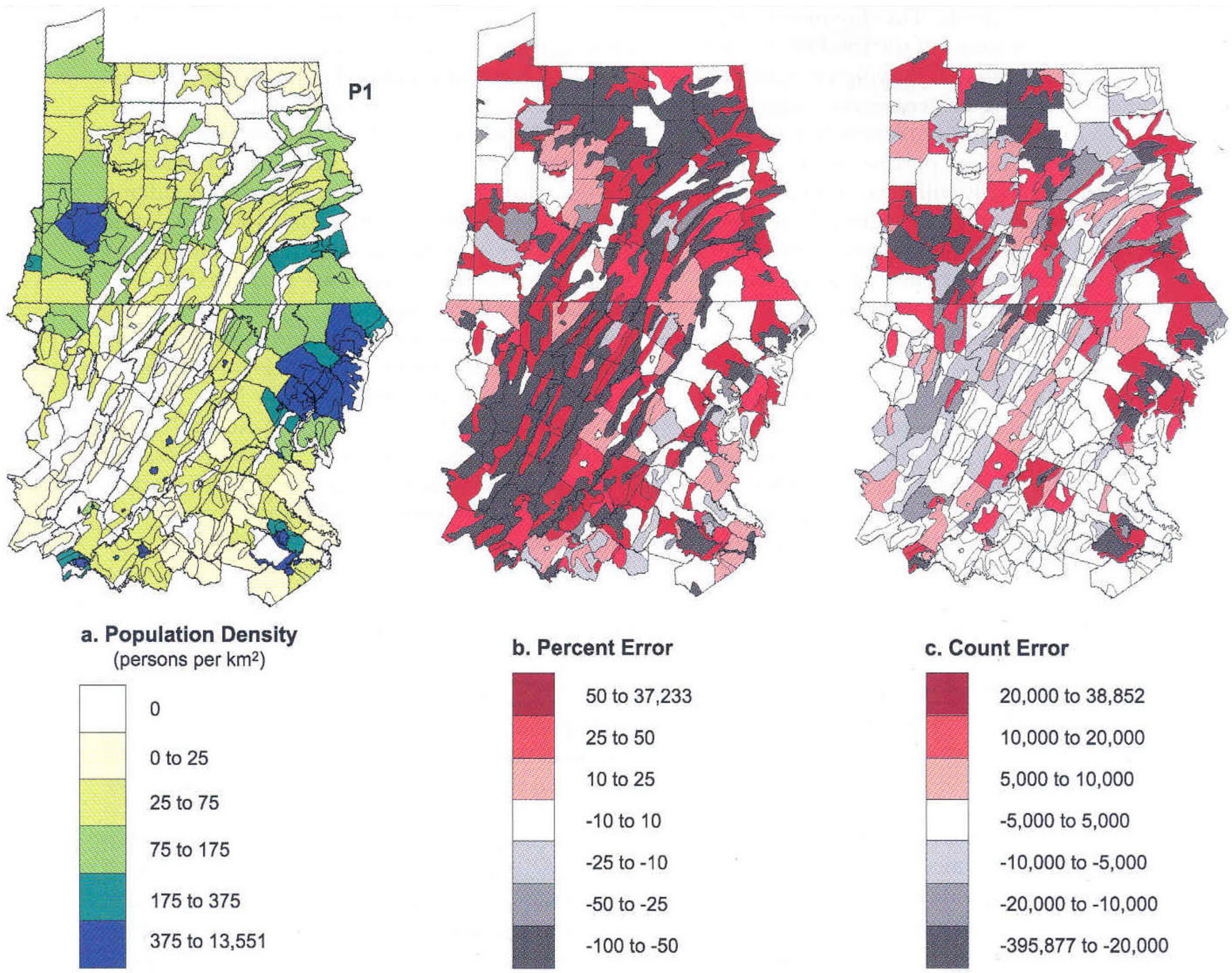
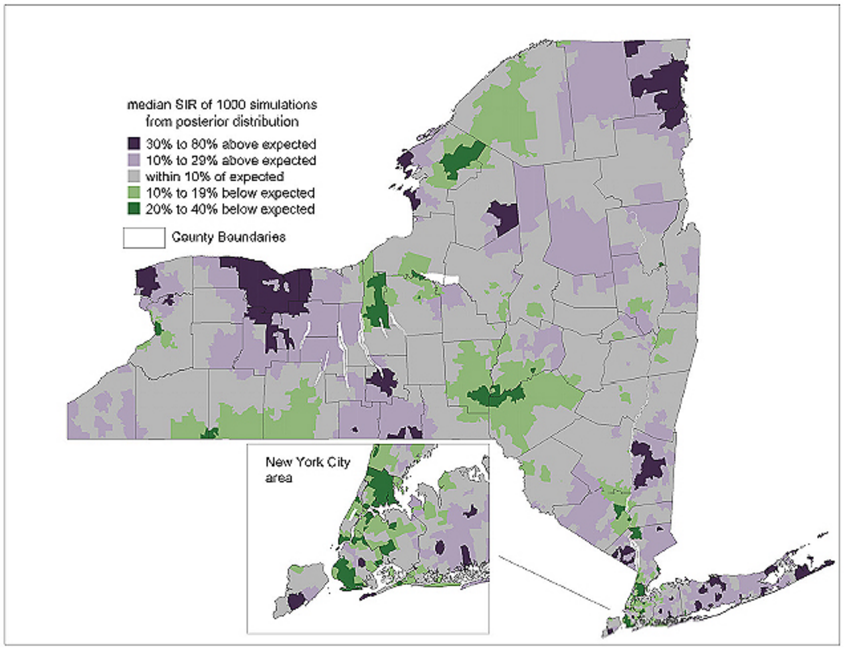


Figure 3.3 The dasymetric method and associated error maps (Eicher and Brewer 2001).



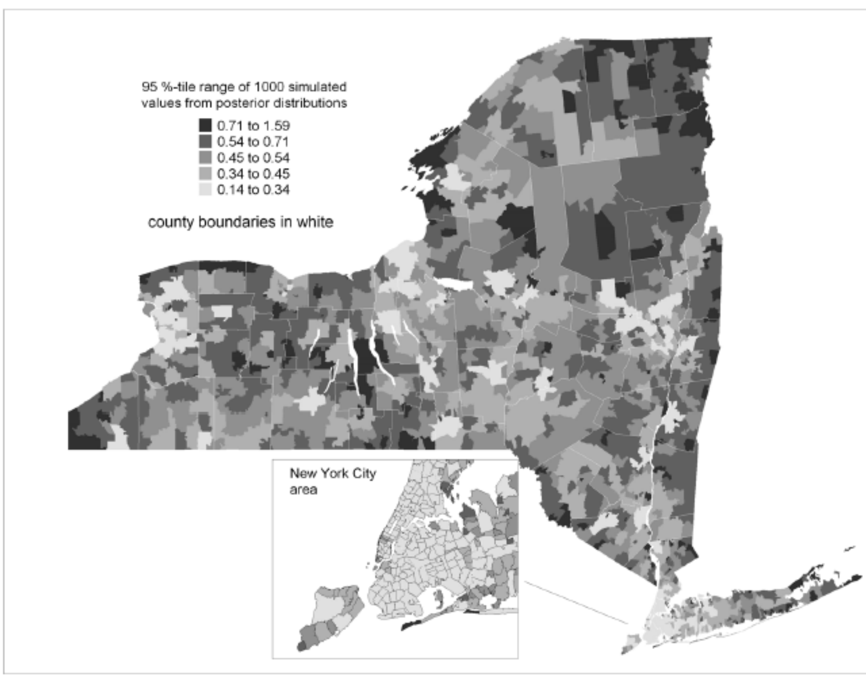


Figure 3.4 Bayes estimation technique used to investigate spatial patterns of prostate cancer incidence in New York State (Johnson 2004).

interpolation techniques such as inverse-distance weighting and splines are limited in health research because many of the techniques are relatively new to the discipline, human and financial resources are limited, and the levels of understanding of how these techniques can be applied are also limited (Cockings, Dunn et al. 2003).

Like many geostatistical techniques, kriging offers an analysis of the spatial dependence within the data, however the accuracy of the estimated values is limited by the interpolation methods (Cromley and McLafferty 2002). For example, in order to properly interpolate a quantile or probability map, a multivariate normal distribution of the measured data must be assumed. The ultimate goal of kriging is to produce a surface of predicted values that enables health risk to be visualized as continuous phenomena. That is to say, certain exposures may occur at discrete points, however the risk of illness or disease exists almost everywhere (Cromley and McLafferty 2002). It is necessary to understand the limitations and appropriateness of geostatistical modeling because there is the potential of negative interpolations (Berke 2004).

The Empirical Bayes method is a smoothing technique that combines probability mapping with choropleth mapping and addresses the small numbers problem. Bayesian modeling was used to investigate spatial patterns of prostate cancer incidence in New York State where population varies in small spatial units (Johnson 2004). Rates calculated for small areas are unstable and rates calculated for large areas are often overemphasized. Statistical significance is related to sample size, thus results based on small areas may not be as meaningful. Therefore, the smoothing process adjusts the rates of the small and large areas to be closer to the mean rate in order to reflect the population size on which the rates are based {Cromley and McLafferty 2002).

As expected, *CaGIS*, a leading cartographic journal not only published the most total number of maps but also published a more diverse range of maps than the other journals. *CaGIS* included more raster maps (or maps with raster-like elements), maps used to visualize geo-techniques, projections, isarithmic, dot, dasymetric, proportional symbol and combination maps than any other journal. In fact in order, the most prevalent map types in this journal are raster or with raster-like elements (62), geo-techniques (60), and reference/location maps (59). The reference and location maps were often snapshots of maps published in studies of specific cartographic techniques such as interactive mapping, geospatial modeling, or visualization. The projection is one map type not seen in any other journal. A projection is the mathematical calculation and presentation of the three-dimensional earth to a two-dimensional surface and is a topic specific to cartographers. More dasymetric and isarithmic maps were also seen in *CaGIS* than in any other journal. This is in part due to the level of expertise of the authors as well as the level of expertise of the journal-reading population. Secondly, it was expected that *CaGIS* show the widest variety of mapping simply because it is a journal dedicated to cartographic research. When the other journals are compared, it can be seen that they do not command nor demand the same level of knowledge of mapping as seen in *CaGIS*.

The public health journal, *IJHG*, and newsletter, *PHGIS* available exclusively in digital format represent 8 and 9 out of the 11 map types respectively, with the choropleth also the most common. These two journals represent the increasing interests in the hybridization of public health and GIS. The commitment to using maps as analytic tools for understanding the distribution and etiology of disease is evidenced in the high number of maps published in these journal, particularly the number of efforts at interactive mapping. Interactive mapping is a progressive area of mapping which promotes a map user-friendly interface allowing for navigation, query and exploration of information in a digital mapping environment (DiBiase 1990; MacEachren 1995; Crampton 2002). The high number of base maps and one dasymetric map published in IJHG suggest that the writing and reading populations of this journal are knowledgeable of sophisticated mapping techniques and are finding ways of applying them to public health. The moderate number of raster maps or maps with raster-like elements and isarithmic maps published in the *PHGIS* newsletter suggest the same. Secondly, the digital format for publication provides an environment conducive to larger file sizes necessary for studies that want to use maps. The digital environment also reduces the increased cost of publication that results from high color content in the graphics.

The three public health journals, *AEP*, *AJPH*, and *AJE* published the fewest total number of maps. Although interests in using maps for public health have increased over the last decade, the primary purpose of these journals is not to publish public health maps. Almost half of the maps seen in these journals were reference or location maps used primarily to delineate the study area. *AJPH* had the most number of choropleths as well as the combination choropleth/dot map or choropleth/proportional symbol map. As discussed earlier, such maps present data at an aggregated level. However, the addition of point level data to a choropleth shows a level of understanding that either two types of data or two different distributions can be depicted on the same map to increase the comparative and cognitive understanding of the phenomena at hand. For example, Barr (2001) used a choropleth to map neighborhood poverty levels by decile and overlaid a dot map of cases of tuberculosis corresponding to block group to show the geographic association of tuberculosis and neighborhood poverty in New York City in 1992 (Barr, Diez-Roux et al. 2001).

Health & Place published the third highest number of maps behind *CaGIS* and *IJHG*. This journal represented a diverse range of maps including 5 of the 11 types of maps with the choropleth representing almost half of the total number of maps. Although the numbers are relatively low, the use of raster maps or maps with raster-like elements and geo-techniques also reflect an advanced knowledge of mapping in the contributors and/or readers of the journal. The diversity of maps used in this journal from 2000-2004 is particularly interesting because the primary function of this journal is to address issues that are of interest to a wide range of disciplines that overlap in the common interest of public health, for example mapping, epidemiology, sense of place, and promotion of health. There were a number of articles in this journal that did not specifically study the etiology or distribution of disease, but rather the sense of place with regards to a certain condition and include studies of community perceptions of obesity, crime, drug abuse, and poverty. These studies are masked in the high numbers of articles that fall in the specialization category of chronic disease/illness/cancer.

Summary

The content analysis of *Annals of Epidemiology, American Journal of Public Health, Public Health GIS News & Information, International Journal of Health Geographics, Health & Place* and *Cartography and Geographic Information Systems* from January 2000 to December 2004 revealed several important trends in public health mapping. Public health mapping is increasing. The choropleth accounted for almost half of the map types published all of the journals, excluding *CaGIS*. The distribution of map types included in public health increased markedly when the digital publications *PHGIS* and *IJHG* were considered. The means by which data is collected can determine the map type as well as the characteristics of the study design.

Because there are other publication outlets dedicated to research in public health, public health mapping, and mapping specifically, this study underestimates the total amount of maps in the literature but does show their increasing importance in the journals surveyed. In contrast, the journals surveyed constitute primary outlets for public health research, outlets for digital communications, an outlet for cartographic communication and provide a valid indication of the quantity of such work being published.

It is interesting, and probably not a coincidence, that the increased number of maps in the literature corresponds to the increased interest in using GIS for public health mapping. GIS is a software package that is available to the public therefore anyone with GIS and a desktop can make a map. However most cartographic research is aimed at improving cartographic design in order to enhance communication with the reader. As new studies in public health develop and evolve in response to newer technologies, improved data sources, and the adoption of newer mapping techniques the relevance maps and mapping should be considered.

The next chapter discusses Foucault's concept of governmentality and how public health GIS today returns to a function of geographic governance. The high numbers of choropleths reflect a process of thinking about disease that was considered problematic in the early 1900s. Not only does defining the health status of a population by political or administrative boundaries create an artificial picture of the true continuous nature of disease, but also it reinforces the collection of large amounts of information in a problematic form simply because it is easy to map in GIS. This form of geographic governance is discussed in terms of mapping disease during two time periods, one where the mapping process formalized new methods of mapping that circumvented the political implications of the choropleth and another where there is a need to translate such processes to digital mapping technologies.

Chapter 4. The Political Implications of Mapping Disease

The goal of this research is to understand how mapping shapes medical geographic knowledge about disease. Chapter 1 discussed mapping disease in terms of geographic governance where health was seen as one aspect of individual daily life where conduct can be governed. Secondly, how information was collected regarding disease was discussed in terms of the dividing powers of governance that produced political conceptions about the human condition as being either normal or abnormal. In this chapter the two case studies of map and mapping disease during two time periods as presented in Chapter 2 and Chapter 3 are discussed to understand how mapping disease and the use of certain type of maps can reinforce ways of thinking about disease that return GIS and disease to a problematic concept of space.

There are political implications of mapping disease. The relationship between politics and the *Atlas of Disease* was discussed in the context of World War II. The mapping process of the atlas was the mechanism for obtaining medical geographic knowledge, such knowledge was important for US policy making in underdeveloped countries, or backwards areas. The objective of Medical Geography was to develop a discipline of studies that would provide facts about the standards of living in areas such as China, Indochina, Central Africa, and Central America. The vicious cycle of poor soil, poor food, and poor health prevented the development of intelligence, culture, agriculture, commerce, and industry in these countries. Oppressed by disease and a poor physical condition, these regions were decidedly in no position to raise their standard of living and provide a sanitary condition (May 1950).

What did the U.S. government have to gain by having knowledge about the remote areas of the world? The expense of resources increased US focus on the political significance of areas where mineral and agricultural fields were more plentiful, namely the "pioneer lands" of undeveloped or underdeveloped countries. World War II depleted the United States of numerous resources. Aside from depleted mineral resources, cultivable land became a highly prioritized and limited resource. Increased agricultural production of foods for export exhausted cropland. Continued production would prevent recovery of the land resulting in soil erosion, destruction and depletion. Additionally, forest resources were depleting at a faster rate than they could naturally grow and an alternative was necessary to the prosperity of the US as a global power (Bowman, 1948).

The cartographic emphasis of the *Atlas of Diseases* can be argued as having geopolitical interest in underdeveloped countries. Cartographic emphasis in an atlas is argued to add geopolitical force and meaning to representation that historically may have legitimized or promoted worldviews prevalent in different places and periods (Harley 1989). The constant threat of war focused geographic interest to return the balance of power and view the world in terms of economic and military advantages (Bowman 1948). "If power is about space, spaces were created through the exercise of power (Black 1997 p.18)." "For what high ends we use power is one center of effort, and how we make use of geography is the other (Bowman 1948 p.9)." The mobilization and control of resources over time and space illustrates power as a fluid medium, requiring various allied networks to achieve common economic, ideological, political, and military goals (Allen 2003). That is to say, post WWII, the world was seen in terms of military and economic advantage.

The knowledge of disease can be argued to have the dividing power of governance. The medical geographic use of describing a place as ‘backwards’ has historical roots in the Age of Discovery when the terms such as modern/backward were used to divide up the world. “The essential moment of geopolitical discourse is the division of space in to ‘our place and their place’; its political function being to incorporate and regulate ‘us’ or ‘the same’ by distinguishing ‘us’ from ‘them,’ ‘the same’ from the ‘other (Dalby, 1991). In the aftermath of WWII, boundaries were drawn between diseased areas and non-diseased areas. These boundaries were not physical but rather symbolic. These external powers exerted on the cartographers of the *Atlas of Diseases* may give insight into economic and social issues surrounding the United States during and after World War II.

Politically it may seem important to draw boundaries between regions at risk for disease to separate them from imposing disease in risk free areas. The problems with deducing such boundaries from a medical map or geographic research are inherent in the data they display or report. Health data reported on countrywide rates of disease are almost always extrapolated from small study samples. It is questionable how representative those samples are of the population at risk due to limitations such as gaps in diagnosis, official reports, and over/under reporting. Non-industrialized countries even today complete less than 10% of the recommended health reports (Kalipeni, 2000). The mapping of health data is only as good as the judgment exercised in its compilation. Quantitative information is at the greatest risk of amplification and simplification. That is missing data may be inferred, not based on recorded observations, and resulting policies may be misleading (Wright, 1942).

It is important to recognize how mapping frames concepts of space because maps and mapping are a way of politically understanding the geographic distribution of disease. The *Atlas of Diseases* was a product of specific political interests in remote areas of the world driven by global movement of military men during World War II. U.S. military experiences in the remote places of the world were defined by encounters with disease in, thus promoting it to top governmental priority. As a result it can be argued that The *Atlas of Diseases* projects a particular way of thinking about the world. A way of thinking that categorizes the world based on disease.

Political economists first invented thematic mapping in the early 1800s as a way of understanding the distribution of the population and its resources in a given territory. Using data collected via the newly implemented census, choropleth maps were used to understand the population in terms of health, education, and income. This type of mapping constituted a way of thinking about disease as a form of geographic governance whereby health and disease were considered an issue of population management. That is that health and disease were an aspect of an individual's conduct that could be predicted, prevented, and ultimately governed. Catalyzed by the cholera epidemics of Western Europe in the mid nineteenth century, thematic mapping techniques such as areal shading were adopted by those interested in understanding the relationship between the social environment and disease (ie: poverty, classes of housing). The presentation of this kind of information led to new demands for geographic symbolization.

By the 1930s and 1940s thematic mapping was invented a second time (Crampton 2004). Wright and other cartographers of time (Raisz) were aware of the limitations of choropleth mapping. When faced with the challenge of mapping the correlation of disease with the natural environment for the *Atlas of Diseases*, Wright formalized the categorization of quantitative data. Wrights experience with population management led him to discover the dasymetric as an alternate to the choropleth. The dasymetric maximized knowledge acquired via a census by applying a geographic understanding of population distributions whereby natural boundaries were considered to delineate areas rather than soley delineating by administrative boundaries.

Wright's translation of the dasymetric appeared in his definition of the chorisogram. This technique was used in the *Atlas of Disease* to map areal data, such as prevalence of cholera data collected by states, delineated not by the political boundaries of the states but rather by topography and the true extent of the population distribution. Knowledge about disease was gained through an understanding of trade and commerce, climate, elevation, and population density. The avoidance of the choropleth and the implementation of the chorisogram signified a way of thinking about disease that constituted knowledge of place. Thus, the table Wright published with 'A Proposed Atlas of Disease' in the *Geographical Review* signifies the second invention of thematic mapping (Light 1944; Crampton 2004). The second invention marked a shift in ways of understanding distributions that eroded the dividing power of governance framed by the understanding of disease as an issue of population.

In an interesting contrast to the *Atlas of Diseases*, public health mapping today returns to the choropleth as the primary technique for understanding the geographic distribution of disease, particularly that of cancer. The atlas represented infectious and noninfectious diseases important to the public health of civilian and military occupied areas. The content analysis of public health mapping 2000 to 2004 represents, on the other hand, public interests in chronic disease and cancer. These interests are medically justified by the most recent National Vital Statistics Report that states the top two causes of death in the US in 2002 were heart disease and malignant neoplasms (cancer). These two causes accounted for approximately one-half (51.3 percent) of all deaths (Anderson and Smith 2005). Certainly industrial, medical, and economic development over the last 60 years has contributed to an increasing knowledge base on the risk factors, environmental causes and exposures for cancer. Similarly, changes from active to more sedentary lifestyles for example, have lead to an increase in obesity, diabetes, heart disease, and other chronic illnesses.

The shift in types of diseases mapped in the atlas and in the public health literature today reflects a method of data collection and representation that returns to problematic ways of thinking that includes health as one aspect of geographic governance. Today mapping relies heavily on centralized databases such as the US census and state and national based cancer registries. Cancer registries were designed in the 1950s by the World Health Organization to collect, organize, store, analyze and interpret intelligence about current cancer burdens and its potential causes. By centralizing these records, cancer control could be implemented, access to hospitals assessed and the value of early diagnosis and treatment evaluated. Patient activity could be monitored to see where and when it would be "cost effective to open new treatment centers." (Muir, Demaret et al. 1985)

The political implications of using choropleths to map data collected from a centralized collection and analysis of health data as seen with cancer registries can be discussed using

Foucault's description of the panopticon. The process of measuring, observing, and treating implemented by surveillance was a type of branding, whereby those with disease were susceptible to the division between normal and abnormal. Today understanding geographic distributions of disease using the choropleth define cancer rates by the administrative units in which the populations live, establishing norms by which these populations are compared for issues necessary for policy making and government.

Why certain populations are at risk for diseases reflects a complex web of geographical, biological, social, economic, environmental, and political issues. Today, geographic factors that shape disease emergence are not limited to the physical environment but also include social, economic, and biological components. The emergence and reemergence of infectious diseases once thought to only threat developing countries with unstable political and/or economic unrest are now threatening developed countries. Growth in human host populations, worldwide environmental changes and increased spatial mobility between humans and pathogens has shaped the 20th century pattern of emerging disease (Haggett 1994). Although many mapping techniques are employed in public health today to understand the complex web of disease, the prevalent use of choropleths returns mapping to a way of thinking that is problematic.

There are a number of complicating factors in understanding geographic distributions of disease. One of the most difficult tasks facing researchers today is the difficulty in obtaining accurate exposure and disease outcome data for the time and place most relevant. Cancer, for example is the result of multiple and varied exposures that occur over long periods of time. How is this information captured? Data are typically scattered across resources and collected by a number of individuals, groups, and agencies each with their own method of organization and calculation. How can this information be compared? And finally, there is the issue of privacy. It is necessary for point level information, particularly that including a patient's residence, to be aggreagated in order to protect rights of privacy. Although these questions are a bit different than those facing researchers sixty years ago, this research lends cartographic and geographic frameworks that can be adapted to address the modern challenges of disease mapping.

This research was conducted in an effort to further understand the role of mapping to understand the geographic distribution of diseases. This research also raises further questions that directly relate to the political, physical, and economic aspects of disease. The increased interest and availability of GIS has increased recognition of the local geographical influences on health, however methods to properly analyze this information are still needed. This research looked at disease mapping in two time periods, the 1950s and 2000s and found different types of maps used to represent knowledge about disease. Today choropleth maps are used to represent cancer, the top cause of mortality in the United States, whereas fifty years ago, infectious diseases were top causes of mortality and no choropleth maps were used. The analysis of the atlas raises questions about what types of symbols are best for representing the phenomena at hand. Wright's chorisogram, for example, reflects the development of a new mapping technique to address questions of disease as well as the development of a geographer's understanding of place.

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Dr. James P. Leake, National Institute of Health, US Public Health Service
Dr. Kenneth F. Maxcy, School of Hygiene and Public Health, The Johns Hopkins University
Dr. Henry E. Meleney, College of Medicine, New York University
Dr. John R. Paul, Section of Preventive Medicine, Yale University School of Medicine
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